Dairying

FORAGE PRODUCTION
AND
CONSERVATION

Textbook for Class XI

Paper III

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PANDIT SUNDERLAL SHARMA CENTRAL INSTITUTE OF
VOCATIONAL EDUCATION
राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

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FOREWORD

Pandit Sunderlal Sharma Central Institute of Vocational Education (PSSCIVE) has taken up an important and innovative project of development of curricula and instructional materials for vocational courses on the advice of the Joint Council of Vocational Education. It proposes to develop/revise competency-based curricula and bring out textbooks, practical manuals, audio and video materials, etc for every course in existence or courses proposed to be introduced at a later date in the higher secondary vocational education system.

The present title shows the commendable work done by the Institute in meeting the requirements of instructional materials for students and teachers Developed through a comprehensive mechanism, the title is the product of significant contributions made by several experts and others This has been duly acknowledged in this book elsewhere All communications and observations on this project should be sent to the Joint Director, PSSCIVE, Bhopal

J S RAJPUT
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New Delhi
November, 2000

PREFACE

The National Policy on Education (1986) envisages that the introduction of a systematic, well-planned and rigorously implemented programmes of vocational education is crucial to the proposed educational reorganization. In support of this, a variety of programmes/courses have been introduced under Centrally Sponsored Schemes at the lower secondary, higher secondary and college levels. The programme at the +2 stage has assumed a big shape

The paucity of appropriate instructional materials (textbooks and practical manuals) is one of the major constraints in implementation of the programme and a source of great hardship to the students offering vocational courses at the higher secondary stage. To supply these materials, several efforts have been made in the past by the erstwhile Department of Vocationalization of Education, NCERT, New Delhi and by the State Governments. A review of efforts by the PSSCIVE, Bhopal revealed that there was a lot of gap between the supply of relevant books for the number of vocational courses and the actual requirement.

To fill this gap, the PSSCIVE, has taken up a project of developing and publishing a variety of instructional materials. The work of this project is being implemented through the mechanism of Working Groups constituted for each course. It includes (i) review of existing curricula and instructional materials, (ii) adoption or adaptation of existing books, and (iii) writing of fresh books

The present textbook entitled *Forage Production and Conservation* is based on the competency-based curriculum developed by PSSCIVE, and fulfils 80-90 per cent requirement of any particular state syllabus. The textbook has been written by outside authors and two members of the Working Group. The textbook has been reviewed by all the members of the Working Group.

I am grateful to the authors for the development of this textbook and to the members of the Working Group for their candid suggestions during development and review. Their names are given elsewhere.

I place on record my appreciation for the untiring efforts put in by Dr M.K Salooja. Project Coordinator of the Working Group in planning and organizing several such meetings which led to the final form of this textbook.

I shall be grateful for any suggestions and observations from readers which would help in bringing out a revised and improved version of this textbook

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November, 2000

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GANDHIJI'S TALISMAN

"I will give you a talisman. Whenever you are in doubt or when the self becomes too much with you, apply the following test :

Recall the face of the poorest and the weakest man whom you may have seen and ask yourself if the step you contemplate is going to be of any use to him. Will he gain anything by it ? Will it restore him to a control over his own life and destiny ? In other words, will it lead to Swaraj for the hungry and spiritually starving millions ?

Then you will find your doubts and your self melting away."

mkGandhi

CHAPTER 1

Indian Soils and Their Classification

SOIL is a universal medium for all living creatures It supplies water, mineral nutrition and mechanical anchorage to the growing plants Plants manufacture feed for animal and food and fibre for man In general, soil is the uppermost layer of the earth's crust formed over thousands of years from the breakdown of rocks It contains complex mineral compounds, organic matter, air, water and many living organisms like bacteria, fungi, protozoa, insects, worms, etc Soil organisms recycle plant and animal wastes to provide plant nutrients and improve soil structure which help in maintaining a proper ratio of air and water for healthy growth of plant roots

1.1 Soil and Mankind

The importance of soil has been recognized by man since ancient times when nomads and other shifting communities were associated with their concomitant animal grazing. They started growing food and fodder crops by flooding in valley soils of Tigris and Euphrates Rivers in Mesopotamia, the Indus in India and Hwang-Ho River in China, which were habitats for flourishing civilizations The increasing demand of food for a growing population compelled them to use unproductive land for cultivation Continuous efforts have been made the world over for increasing the productivity of the soil because of the limited land availability At present, there is a need to use scientific methods for management of soil for sustainable production of crops and livestock without losing the fertility and health of the soil

1.2 Definition of Soil

The word soil has many different concepts and meanings depending on its uses. The farmer or gardener looks upon the soil as a habitat for plants. As per modern concept, soil is considered as a three dimensional, dynamic, natural body occurring on the surface of the earth. It is a medium for plant growth and its characteristics have resulted from the forces of climate, and living organisms acting upon parent material, as modified by relief, over a period of time.

1.3 Soil Profile

A vertical section of the soil from the surface to the underlying unweathered material is called a soil profile. It is differentiated into different layers which are regarded as horizons. The horizons in a profile can be designated as follows (Fig 1 1)

- O Horizon
- A Horizon
- B Horizon
- C Horizon
- D Horizon

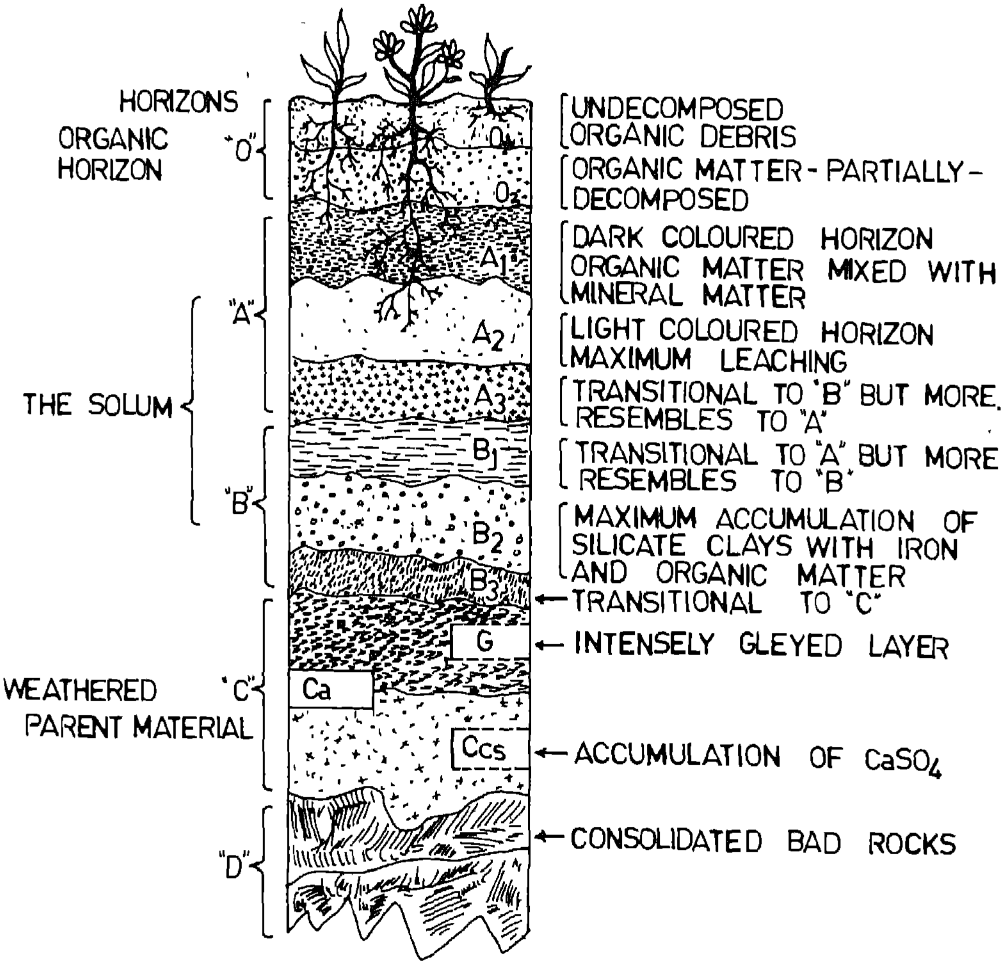

HORIZONS
ORGANIC HORIZON
"O"
O_1
O_2
UNDECOMPOSED ORGANIC DEBRIS
ORGANIC MATTER - PARTIALLY - DECOMPOSED
"A"
A_1
DARK COLOURED HORIZON ORGANIC MATTER MIXED WITH MINERAL MATTER
A_2
LIGHT COLOURED HORIZON MAXIMUM LEACHING
A_3
TRANSITIONAL TO "B" BUT MORE. RESEMBLES TO "A"
THE SOLUM
"B"
B_1
TRANSITIONAL TO "A" BUT MORE RESEMBLES TO "B"
B_2
MAXIMUM ACCUMULATION OF SILICATE CLAYS WITH IRON AND ORGANIC MATTER
B_3
TRANSITIONAL TO "C"
G
INTENSELY GLEYED LAYER
WEATHERED PARENT MATERIAL
"C"
Ca
Ccs
ACCUMULATION OF $CaSO_4$
"D"
CONSOLIDATED BAD ROCKS

Fig. 1.1 Hypothetical Soil Profile

1.3.1 'O' Horizon

The top organic horizon results from the litter derived from dead plants and animals. This layer ordinarily occurs in forest soil and is further divided into O1 and O2 horizons depending on their decomposition.

1.3.2 'A' Horizon (Zone of eluviation)

This is the mineral horizon which lies below 'O' near the surface and is characterised usually as the zone of intensive leaching. This horizon is designated as A1, A2 and A3 depending on identifying characters, 'A3' is transitional layer to 'B' but more like 'A' than 'B' horizon.

1.3.3 'B' Horizon (Zone of illuviation)

This horizon occurs immediately below 'A' horizon in which accumulation of iron and aluminium oxides, salts and clays has taken place from 'A' horizon. This is further divided into B1, B2 and B3 horizons depending on identifying characters This position of soil profile is developed by soil forming process distinguished from parent material immediately below it The 'A' and 'B' horizons together are called the 'solum'

1.3.4 'C' Horizon

This is the unconsolidated parent material underlying the solum. The horizon differentiation is generally found absent in case of alluvial soils.

1.3.5 'D' Horizon

The consolidated parent rock under the parent material is termed as 'R' layer of bedrocks

1.3.6 Importance of Soil Profile

A soil profile is a historic record of all the soil forming processes The type of profile depends on the climate, vegetation, parent rock and age of the soil Every well-developed, undisturbed soil has its own distinctive profile characteristics, which are utilized in soil classifications and survey. Studying of a soil profile has great practical importance in the proper management of soil

1.4 Soils of India

In India we have 143 million hectares land under cultivation out of 326.7 million hectares total land area (Table 1.1). About 49 million hectares soils are acidic which predominantly occur in high rainfall area and 7 million hectares are salt affected These soils have low productivity and need proper management.

1.5 Traditional Classification

This classification is based on the topography, regolith and climate Indian soils are mainly covered in the following eight broad groups.

1.5.1 Alluvial Soils

Alluvial soils are derived from water deposited sediment and do not show prominent horizon development These soils are found in river basins mainly in Indo-Gangetic flood plains, coastal and deltas in the states of Punjab, Uttar Pradesh, Bihar, West Bengal and in some parts of Assam and Orissa The soils in river deltas on the coasts is termed as deltaic alluvium The alluvial soils on sub-mountain regions and low lying tracts of Tarai in Uttar Pradesh, Bihar and Bengal are called *bhabar.* The old alluvium is named as *bangar* and recent is called *khadar.*

These soils differ greatly in texture

Table 1.1 · Area Under Various Groups of Soils in India

Sl No	*Soil Group*	*Area (Million Hectares)*
1	Alluvial soil, riverine old or recent, non-saline, non calcareous	101.2
2	Alluvial soil, highly calcareous saline and alkaline	15.7
3	Coastal alluvial	8.5
4.	Deltaic alluvium	18.0
5	Pedocal sierozem and pedocal brown of alluvial origin	7.4
6	Desert soil	14.2
7	Medium black and shallow black	27.2
8	Black saline and alkaline soil	20.4
9	Mixed red and black soil	11.5
10.	Red soil	22.4
11	Red mix yellow soil	19.8
12	Laterite soil	24.8
13	Forest and brown soil	19.0
14	Podsolic, foothill/Tarai Mountain soil	11.7
15	External snow and peat	4.9
	Total	326.7

and consistency ranging from sand to loam and silt to heavy clays. The alluvial soils are generally deficient in nitrogen, humus and occasionally in phosphorus. Potash is usually sufficient Such soils are best suited for paddy cultivation but other grains and forage crops can also be grown very well in central and western part of Indo-Gangetic Plains

1.5.2 *Arid and Desert Soils*

Sandy soils have developed in the arid regions of Rajasthan, Rann of Kutch in Gujarat and south western part of Haryana. The great desert of Rajasthan is known as *thar* These soils are very light and severely affected due to water and wind erosion Shifting or partially established sand dunes are common These soils are alkaline in nature and have poor fertility but respond fairly if irrigated *Bajra, guar,* cowpea and oats are generally grown on these soils

1.5.3 *Black Soils*

These soils have mainly developed from a vareity of basic parent materials such as basalt and schists These soils are found in Karnataka, Andhra Pradesh, Tamil Nadu and in some parts of West Madhya Pradesh, Maharashtra and West Orissa. Black soils have thick dark brown to black surface horizon relatively poor in organic matter. The black colour may be due to presence of titaniferous magnetite compounds. These soils are also called *regur* or black cotton soils due to their eminent suitability for growing cotton. They are high in clay content which remains usually uniform throughout the profile.

These soils are sticky and plastic when wet due to high content of montmorillonite clays. They show strong swelling and shrinkage with change in moisture and produce wide and deep cracks. The tillage and management practices are problematic for efficient utilization of these soils. They have very high cation exchange capacity, and have high calcium, magnesium and potassium but are low in nitrogen, phosphorus and sulphur. Crops like sorghum, cotton tobacco, groundnut, black gram, green gram and shallow rooted crops are suited for cultivation

1.5.4 Red Soils

These soils are derived from parent material rich in fero-magnesium minerals which exhibit red to brown colour with varying degree of its hydration. Such soils generally occur in the Deccan Plateau and Damodar Valley. These soils cover large parts of Tamil Nadu, east Andhra Pradesh and Madhya Pradesh. They are also found in Naga Hills in Assam; Bundelkhand region of Uttar Pradesh; and Aravali Hills of Rajasthan.

These soils are light in texture and easy to cultivate They are poor in organic matter and plant nutrients. The clay is constituted of Kaolinite type and is neutral to acidic reaction. These soils are good for grassland purpose. Finger millet (*ragi*), groundnut, horsegram, paddy and almost all forage crops are generally cultivated as per availability of irrigation.

1.5.5 Laterite Soils

These soils are deeply weathered and formed under tropical humid climate favouring downward leaching of silica and bases. Iron and alumina remain at the surface They occupy, along with Western Ghats, hills of Deccan, Eastern Ghat, Karnataka, Madhya Pradesh and certain parts of Orissa, Assam, Mysore and Malabar. These soils are mostly acidic, the pH sometimes being as low as 4. These soils are generally less fertile but are agriculturally important due to their good physical condition and fair resistance to erosion The crops grown on these soils are deficient in calcium which affect the overall growth of animals fed on them.

1.5.6 Podsolic, Foothill/Tarai and Mountain Soils

Podsolic soils have a raw organic matter layer over a light grey, strongly leached sandy horizon. The colour is dark brown to reddish due to accumulation of iron oxide and organic matter in 'B' horizon. In high rainfall areas (>2,000 mm), the soils are acidic, coarse in texture whereas, in low rainfall areas (600 to 1,000 mm) sodic soils occur extensively.

In hilly areas of high rainfall and in foothills the water erosion in rainy season and water stress in non-rainy periods are major problems. They are not very important agriculturally, being found mainly under forest. Maize localized in hilly areas and paddy in Tarai and valleys are the main kharif crops Sugarcane and wheat are the major rabi crops in some other areas

1.5.7 Salt Affected Soils

The salt affected soils are also called *reh, kallar* and *usar* In many parts of Bihar, Uttar Pradesh, Punjab and Rajasthan soluble salts mainly chloride and sulphate of calcium, sodium and magnesium accumulate in the surface layer of soils which do not allow crops to grow. The structure of these soils deteriorates and the soils become infertile.

1.5.7.1 Types of Salt Affected Soils

The salt affected soils are mainly divided into following three classes

(i) *Saline Soils* · These soils have a white crust of salts on the surface in the dry season. The electrical conductivity of saturation extract is more than 4 dS/m (Deci Simon per metre) or more than 0 8 dS/m in 1.2 soil water suspension and exchangeable sodium is less than 15 per cent. The pH is less than 8.5,

(ii) *Saline Sodic Soils* ' Those soils which have electrical conductivity of saturated extract more than 4 0 dS/m and exchange-able sodium percentage less than 15 per cent. The pH may or may not be more than 8 5.

(iii) *Sodic Soils* · These soils contain exchangeable sodium percentage greater than 15 per cent, as a result the pH increases more than 8 5. The electrical conductivity of saturation extract is less than 4.0 dS/m In sodic soils, there is a dark or blackish salt encrustation on the surface On drying, it is cloudy, hard, compact and difficult to work with. Rain water does not move and remains standing for a longer period.

1.5.8 Peaty and Other Organic Soils

Organic soils include bog, half bog, peaty, marshy and swampy soils. These occur in coastal marshes or in inland swamps and in various depressions in mountain areas The marshy soils are also found in the coastal tract of Orissa, Sunderbans in West Bengal, north Bihar, Almora in Uttar Pradesh and south west of Tamil Nadu.

These soils are poorly drained with high un-decomposed organic matter and have high ground water table with very poor drainage almost throughout the year

These have very little agricultural value unless reclaimed and well managed.

1.6 Land Capability Classification

This classification is based on the inherent characteristics of soil in combination with climate, landscape features, erodibility and other natural hazards that limit the use of land Scientific survey and classification of soil units after field and laboratory studies and their correlations give out the specific class which respond to similar plant growth, use and management practices.

The classification of soil units provides information on the nature of parent material, colour, texture, structure of soil, type of clay minerals, consistence, permeability, depth of soil, soil reaction and root distribution along the depth of soil profile. Each of the above factors has a definite role to play in behaviour of soil and its management Climatic conditions and landscape features like slope and erosion conditions may limit the safe and productive use of soil Apart from this, some other un-favourable features such as stoniness, salinity and alkalinity, high water table, hard clay pan, etc. limit the proper use of soil unless corrected and removed timely

Land capability of classification is made up of the following three categories .

1.6.1 Capability Classes

There are eight capability classes denoted in Roman numbers. Class I-IV include lands suited for cultivation. However, they can also be used for other purposes Class I is the best suited for agriculture but in II-IV classes some limitations are imposed progressively and hence soil conservation measures are needed for cultivation Class V to VIII are primarily not suited for cultivation and should be maintained under natural vegetation of forest and grasses Class VIII lands are mainly suited for wildlife, recreation and watershed protection (Table 1.2)

1.6.2 Capability Sub Classes

Classes are divided into sub-classes on the basis of erosion (e), wetness (w), rooting zone limitation (s) and climatic conditions (c) and are denoted as IIc. IIs, IVc and so on. There are no sub-classes in Class I

1.6.3 Capability Units

These are the further sub-divisions of sub-classes on the basis of fairly similar conservation and management practices.

Land capability classes can be changed any time on improving or deteriorating of existing limitations.

1.7 7th Approximation Soil Classification

The soil survey of United States Department of Agriculture has proposed a new comprehensive system which is classified in Approximation, 1960. This classification takes care of both moro-phology of oils and all climatic factors together.

The systems classify the soils into several categories as orders, sub-orders, great groups, sub-groups, families, series and types. The nomenclature used consists of coin terminology derived from many languages and is self explanatory. There are eleven orders which have been suggested on the basis of common soil properties and similar horizon

Table 1.2 : Land Capability Classification

Land suitable for cultivation				*Land not suitable for cultivation*			
Very good land with no limitation	*Good land with minor limitation*	*Moderately good land with major limitation*	*Fairly Good land with occasional cultivation and minor limitation*	*Suitable for pasture*			*Suitable for wildlife and water shed*
				With no limitation	*With minor limitation*	*With major limitation*	
Class I	Class II	Class III	Class IV	Class V	Class VI	Class VII	Class VIII
→ → Degree of permanent limitation → →							

differentiation (Table 1.3). Efforts are being made in India and other countries to classify the soils according to this new natural soil classification which can accommodate all types of soils the world over.

Table 1 3 : Classification of Major Groups of Indian Soil as per '7th Approximation' System

Sl No	*Order of 7th Approximation*	*Indian soil groups*
1.	Entisols	Alluvial soils
2	Vertisols	Grumusols
3.	Inseptisols	Andosols, volcanic ash and mountain soils
4	Mollisols	Chestnut, planosols, brown forest soils
5	Spodosols	Podzols
6.	Alfisols	Non calcic brown soils, red brown
7.	Ultisols	Grey hydromorphic soils
8.	Oxisols	Lateritic soils
9.	Histosols	Organic soils
10.	Aridisols	Desert soils, saline and alkali soils
11	Andisols	Volcano soils

QUESTIONS

1. Define the soil and give its components.
2. Differentiate between the following
   (i) Saline and sodic soils
   (ii) Acid and salt affected soils
   (iii) Laterite and podsolic soils
   (iv) Coastal alluvium and riverine alluvium.
   (v) *Bangar* and *Khadar* soils
3. What is soil profile? Describe it in detail.
4. Write the basis of land capability classification. How does it help in crop production?
5. State whether the following statements are True or False.
   (i) Sandy soils are developed in a humid climate.
   (ii) Black soils swell and shrink due to their high clay contents.
   (iii) Saline soils contain exchangeable sodium more than 15 per cent.
   (iv) Red soils have the colour due to fero-magnesium mineral.
   (v) Laterite soils are generally found to be alkaline in nature
6. Write short notes on the following :
   Peat soils, Horizon, Sodic soils, 7th Approximation soil classification and sand dunes.

CHAPTER 2

Physical and Chemical Properties of Soil

THE soil consists of all three phases viz. solid, liquid and gaseous. The solid phase, composed of mineral and organic matter, occupies nearly/half of the soil volume. Solids make up the major portion of soil mass. The liquid phase is constituted of water with small amount of soluble salts. The gaseous phase is relatively richer in carbon dioxide than atmospheric air due to respiration of soil microbes and plant roots. These phases are intermixed in such a way that they could not be separable from each other. Solid particles are interspersed with pore space and capallaries which are filled up with air and water. The space occupied by air and water together constitutes about 50 per cent of soil volume and both bear an inverse relationship between them. As the volume of water in soil mass increases on rain or irrigation the air decreases accordingly. The reverse is true on the removal of water by drainage and evaporation and/or transpiration of plants. The distribution and arrangements of mineral and organic part of solid phase in different fashion affect the other two phases which in turn modify both physical and chemical properties of the soil. Physico-chemical properties of soil greatly influence its use and behaviour towards plant growth.

2.1 Physical Properties

The anchorage of plant, penetration of roots, drainage, aeration, retention of moisture and availability of plant nutrients are primarily linked with the physical conditions of the soil. Some of the important physical properties such as texture, structure, density, porosity, consistency, colour, moisture and temperature are discussed here.

2.1.1 Soil Texture

The soil within the profile contains different sized mineral particles, coarse sand (2.0-0.2 mm diameter), fine sand (0.2 - 0.2 mm), silt (0.02 - 0.002 mm) and clay (<0.002 mm). The relative proportion of these different sized particles is known as texture. The general characteristics of the soil separates are given in Table 2.1.

Large surface area linked with small particles is primarily a function of particles size affecting all physical properties of the soil. The soil type depends greatly on the proportions of these soil particles. If a soil predominates in one size particles, it may be called clay, silt or sand. On equitable proportion of coarser and finer particles, it is known as loam. The exact texture of soil can be determined with the help of the triangle (Fig 2.1), if percentage of any two particles (sand, silt and clay) are available. The limits of these particles are also indicated in Table 2.2.

Sandy soils possess good drainage and aeration. These are usually loose, friable and easy for use during tillage operation. On the other hand, clay soils have fine pores, moderate to poor in drainage and aeration, and are relatively difficult to handle for cultivation purpose. Clay and silty soils have high adsorptive or retentive capacity for moisture, gases and nutrients. Each type of texture has its own advantages and disadvantages. The textural classes of soil can be worked out approximately by sense of feeling method. Take out about half a handful of top dry soil and add water gradually until the particles form a ball. Then rub the soil ball between thumb and finger and follow the flow chart (Fig. 2.2).

Table 2.1 : Characteristics of Soil Particles

Soil separates	*Diameter** *(mm)*	*Feel of soil separates*	*Composition*
Coarse sand	2.00-0.200	Very gritty	Primary minerals
Fine sand	0.20-0.020	Gritty	Primary minerals
Silt	0.02-0.002	Flour like	Primary and secondary minerals
Clay	< 0.002	Very smooth	Secondary minerals

* International system proposed by Atterberg

Table 2.2 : Percentage of Sand, Silt and Clay in the Principal Textural Classes

Textural classes	*Range in per cent*		
	Sand	*Silt*	*Clay*
Sand	85-100	0-15	0-10
Loamy sand	70-90	0-30	0-15
Sandy loam	43-80	0-50	0-20
Loam	23-52	28-50	7-27
Silt loam	0-50	50-88	0-27
Silt	0-20	8-10	0-12
Sandy clay loam	45-80	0-28	20-35
Clay loam	20-45	15-53	27-40
Silty clay loam	0-20	40-73	27-40
Sandy clay	45-65	0-20	35-45
Silty clay	0-20	40-60	40-60
Clay	0-45	0-40	40-100

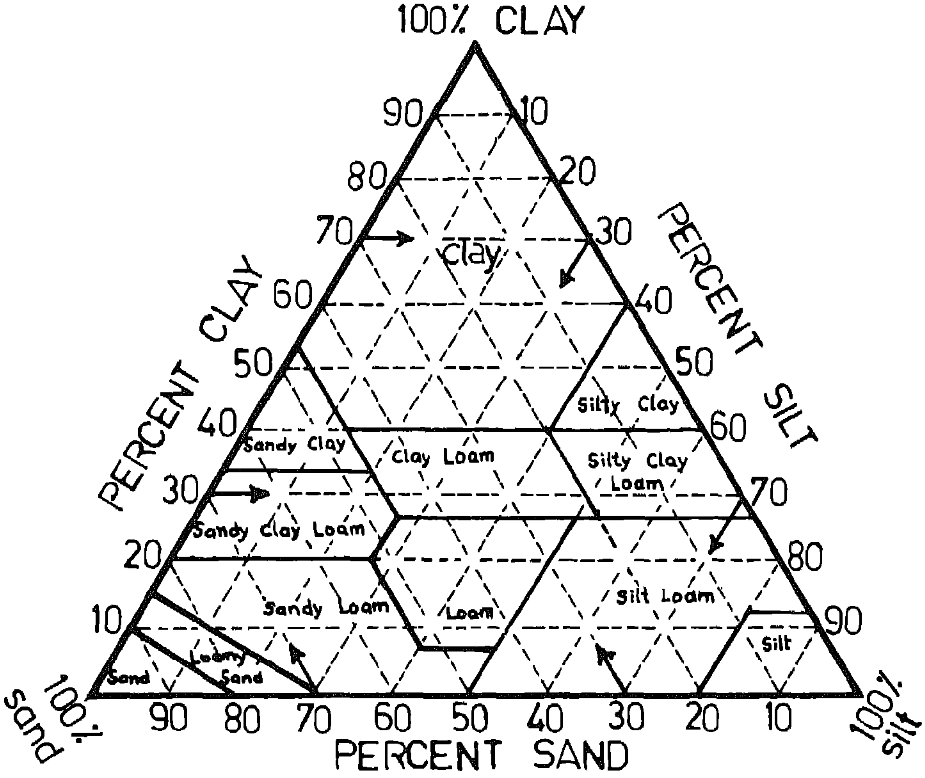


Fig. 2.1 Triangle Diagram to Determine Textural Class of Soil

2.1.2 *Soil Structure*

The arrangement of individual particles and their aggregates into a certain defined pattern in the soil mass is called structure Soil aggregates are formed by binding or cementing different particles through polysaccharides, polyuronides, plant roots, colloidal organic matter, lime, oxides of iron and alumina, fungal mycelium and bacterial gums. Many salts are coagulated or flocculated soil colloids which are aggregated again

The most important types of structure are columnar, prismatic, platy, angular and sub-angular blocky, spherical, crumby and granular (Fig. 2.3). The structure of cultivated soils has a very important bearing on their water holding capacity, drainage, ease of tillage and root penetration, general productivity, residence for soil organisms and resistance to erosion by wind and water The crumb and granular structure are the most favourable for plant growth. Soil structure can be improved by using different management practices such as ploughing, draining, liming, fertilizing and manuring of soil at a proper time.

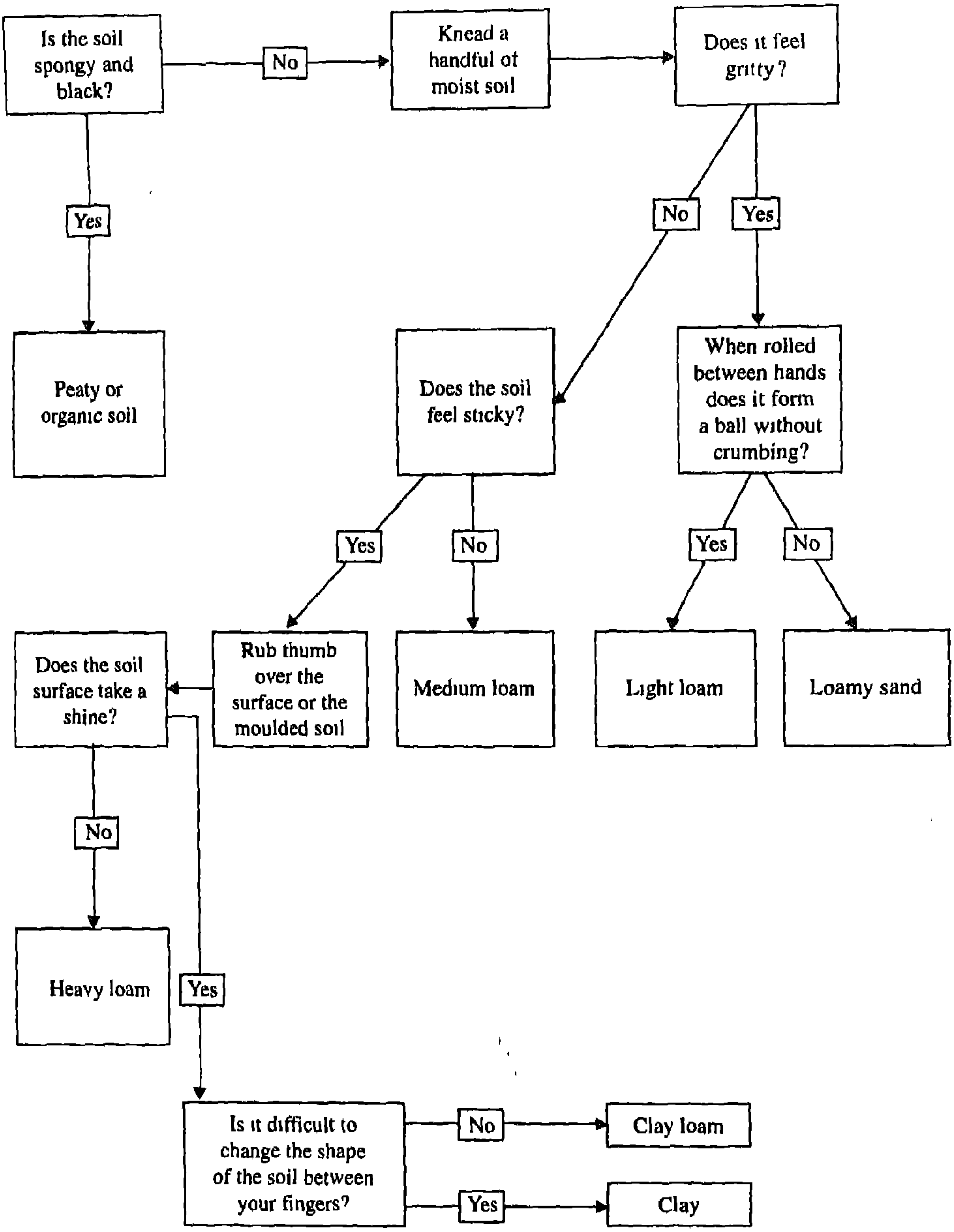

Is the soil spongy and black?
No
Knead a handful of moist soil
Does it feel gritty?
Yes
Peaty or organic soil
No
Yes
Does the soil feel sticky?
When rolled between hands does it form a ball without crumbing?
Yes
No
Yes
No
Does the soil surface take a shine?
Rub thumb over the surface or the moulded soil
Medium loam
Light loam
Loamy sand
No
Heavy loam
Yes
Is it difficult to change the shape of the soil between your fingers?
No
Clay loam
Yes
Clay

Fig. 2.2 Flow Chart to Work Out the Soil Type by Sense of Feeling

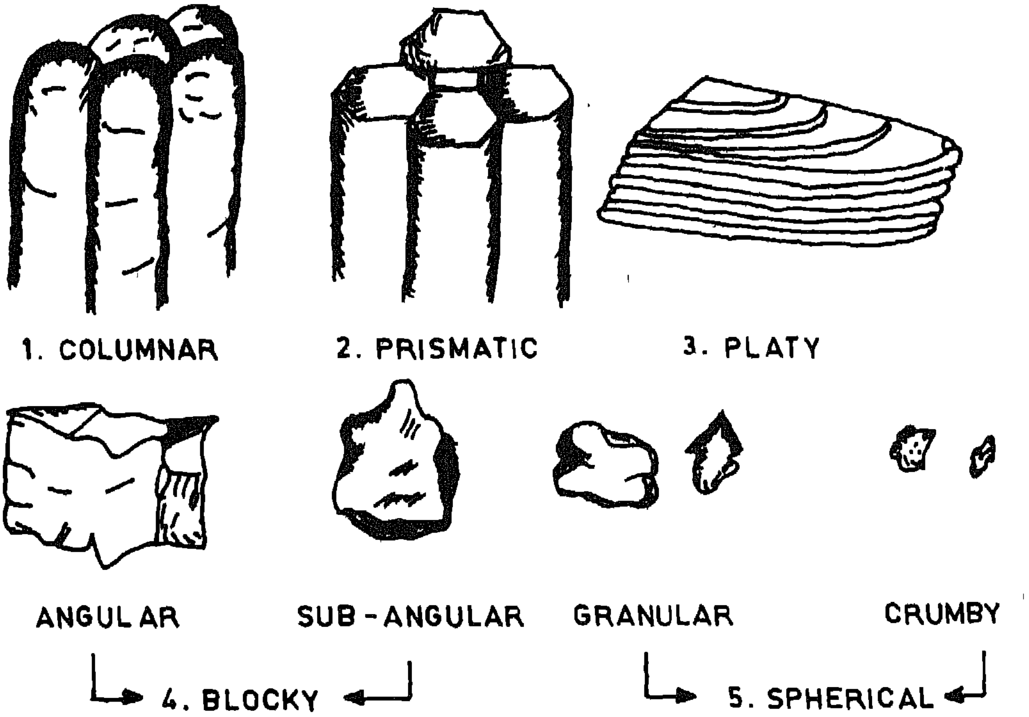


Fig. 2.3 Five Major Types of Soil Structure

2.1.3 Soil Density

Particle or true density is the weight per unit volume of solid portion of soil. Soils having larger particles are usually heavier than those with smaller particles. However, bulk or appearent density is the weight per unit volume of oven dry soil inclusive of pore space. It is always lower than the particle density. Generally, soils with low bulk densities have favourable physical conditions whereas, those with high bulk densities exhibit poor physical conditions The bulk density of one cubic metre of sandy, sandy loam and loamy soils varies from 80-100 kg per cubic metre while silt loam, clay loam and clay soils ranges from 70 to 100 kg per cubic metre. Soils having high particle density anchor the plants more strongly.

2.1.4 Soil Porosity

Porosity refers to the percentage of void space in the soil volume It is calculated by following expression.

Pore space (%)

$$= 100 - \left(\frac{\text{Bulk density}}{\text{Particle density}} \times 100 \right)$$

Porosity of soil varies with texture, shape of individual soil particles, soil structure, amount of organic matter and the compactness. In sandy soil pores are quite large but total pore space is smaller than fine texture soil The porosity varies from 32 to 50 per cent in sandy to clay soil. Granular structure and presence of organic matter increase the porosity of soil which is conducive to good drainage and easy for tillage practices.

2.1.5 Soil Plasticity and Cohesion

Soil plasticity refers to the ability of moist soils to change shapes on the application of force and retain this shape when the force is removed. Plasticity of soil increases with increase in its clay content. Soils containing montmorillonite type of clay are more plastic than soils having Kaolinite type of clay.

Cohesion is the tendency of particles to stick to each other. Cracks developing in clay soil and clods forming on their ploughing are due to the cohesive nature of clay particles

2.1.6 Soils Colour

The colour of the soil is an important criterion in description and classification of soils. It indicates the composition as well as the condition of the soil. Dark brown to black colour of soil denotes a high content of humus and associated with good soil structure Red colour is generally suggestive of relatively old and intensely weathered well drained soil. Brown colour is mainly due to a mixture of organic matter and iron oxide.

The reduction of iron compounds gives the soil greenish or bluish colour which is injurious to the root growth. White or black surfaces of soil associated with accumulation of alkali salts make the soil least fertile The surface soils are usually darker than subsoil because of their high organic matter content

2.1.7 Soil Temperature

Proper temperature is necessary for seed germiantion, root growth and microbial activity of the soil. All the soil processes are almost ceased at or near the freezing point of water. Radiation from the sun is the primary source of soil heat. The temperature of the soil is influenced by its colour, texture, slope and water contents. Dark coloured soils absorb more heat than the lighter ones. Sandy soils absorb more heat during day and lose it at night quicker than the fine grained silt and clay. Good soil tilth retards evaporation of water from surface, reduces its cooling effect and helps in warming up of the soil.

2.1.8 Soil Air

Air is needed by plant roots and soil micro-organisms Nitrogen fixing bacteria residing in the root nodules utilize gaseous nitrogen present in the air. Air is found in any pores that do not contain water. Non-capillary pore space generally retains the air which is held by colloids or dissolved in the solution.

It is vital to have porous soil to replenish the oxygen in the soil by having inter-culture in standing crops or by deep ploughing The occupation of one third pore space by air and two thirds by water is considered a more favourable condition for plant growth.

2.1.9 Soil Water

Soil water is essential to complete the plant life and plays a significant role in soil plant growth relationship. Plants need the water :

(i) as part of their make-up

(ii) as a solvent and carrier of plant nutrients

(iii) for body function such as photosynthesis and transpiration

(iv) for rigidity of plant cells and regulating their temperature

The following standard terms are used to describe the retention of water in the soil

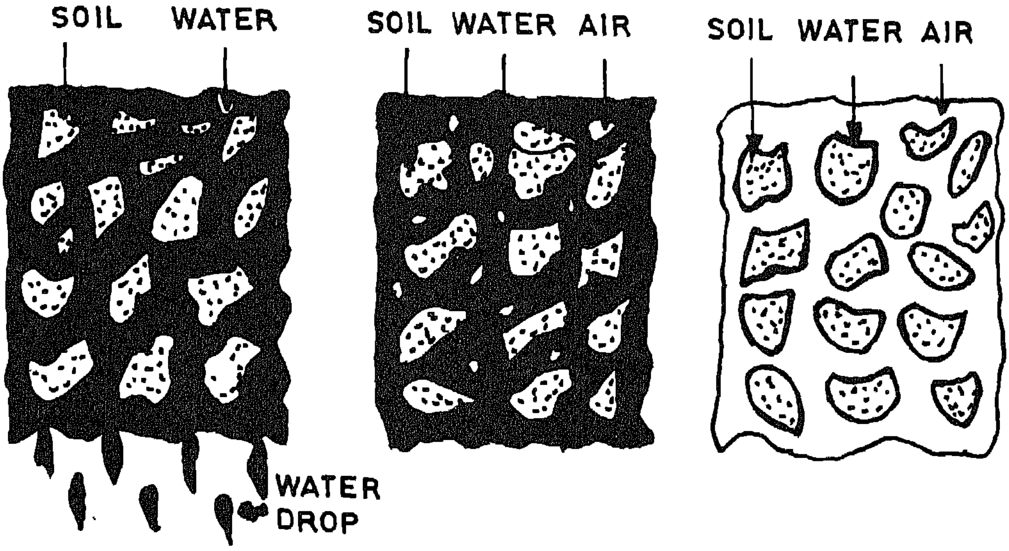
(i) *Saturation* . The soil is said to be saturated when all the pores are filled with water (Fig. 2.4)

(ii) *Field Capacity* It is the capacity of the soil to retain water against the downward pull of the force of gravity (Fig. 2.4)

(iii) *Permanent Wilting Point* . When the water left in the soil is held so tightly by soil particles that the plant can not get it and wilts In other words, the moisture of soil at which a plant wilts and is unable to recover (Fig. 2.4)

(iv) *Available Water* : Between field capacity and wilting point, the water is available to the plant roots It is generally held in pores of capillary size by surface tension and the attraction of water molecules by each other Sandy and most clay soils have relatively little available water whereas sandy loam, silty loam and peaty soils hold more water provided they are well structured

(v) *pF Value* Soil moisture is measured in terms of pF value in the same way as in case of pH value pF denotes the logarithmic value for tension shown



SATURATION FIELD CAPACITY WILTING POINT

Fig. 2.4 Diagramatic Scheme for Showing Soil at Saturation, Field Capacity and Wilting Point.

in terms of the height in centimetres of a water column. The pF value of oven dried soil is about 7.0. At hygroscopic point, it is about 4-5 at the wilting point, it is about 4.2 and at field capacity, it is about 2.5.

2.1.9.1 Conservation of Soil Water

The loss of soil water occurs mainly through percolation, evaporation and transpiration. The adoption of following suitable practices can minimize the loss of water

(i) *Percolation Loss* : During the rainy season or at the time of irrigation, the excess water percolates downwards to the ground water or stream flow. Percolating water leaches out the essential plant nutrients especially nitrogen from the soil Such nutrient loss can be minimized by adding organic matter and by adopting suitable cropping practices.

(ii) *Evaporation Loss* : The evaporation loss of water from soil depends on temperature, humidity, wind velocity and soil coditions. Keeping the soil under vegetative cover is the best way to reduce evaporation. Agricultural practices such as mulching, certain tillage operations and plantation of wind breaks can help to reduce evaporation.

(iii) *Transpiration Losses* : Transpiration is an essential physiological phenomenon for the growth of plant. The ratio between units of water transpired by plant to produce one unit of plant dry matter is called transpiration ratio. This ratio varies from 200-500 in humid region and to twice in arid regions. Transpiration is also influenced by temperature, humidity, wind velocity, moisture content and inherent characteristics of the plant.

Some crops like banana, rice, sugarcane, potatoes, etc. having high transpiration ratio and need more water while others like millet, sorghum having low transpiration ratio, are suitable for dry soil and low rainfall areas Selection of crops and weed control can help in reducing the undesired transpiration of water.

2.2 Chemical Properties

The soil chemical properties largely depend on the parent rocks and their minerals from which soil is derived and dominating soil forming factors. Natural soil vegetation also changes the chemical behaviour of the soil. The soil originated from granite rhyolite, sandstone and gneiss minerals are acidic while others from basalt, gabbro, limestone and diabase have alkaline nature and contain more of calcium, magnesium, sodium and potassium content. Intense weathering and leaching may produce less productive soils even from rocks and minerals which are originally rich in essential plant nutrients.

Selection of crop should be based on the chemical nature of the soil or else the nature of soil can be changed to some extent by adopting suitable soil management practices as per our requirements. The main chemical properties of soil are explained here.

2.2.1 *Soil Reaction*

Soil reaction is the most important single chemical characteristic which not only determines the production potential for most of the crops but also provides the basis of soil development Soil reaction denotes whether it is acidic or alkaline It is measured on pH scale from 1 to 14 (Fig. 2.5). A pH value of 7.0 denotes a neutral soil. As the pH decreases, soil becomes increasingly acidic and as it increases, the soil becomes increasingly alkaline (Fig. 2.5). Soil pH ranges from about 3.5 to 10.5 and affects the soil life, structure, nutrients availability and plant growth. Most of the plants prefer a soil pH of 6.5 to 7.5 for their growth (Fig. 2.6) and all plant nutrients are generally available between pH range of 6.5 to 7.5 (Fig 4.3)

2.2.2 *Cation Exchange Capacity*

With the fundamental of colloidal concept stated in Chapter 3, clay and humus colloids have a net negative charges on their surfaces and adsorb the positively charged cations such as NH_4+, K+, Na+, H+, Ca++, Mg++, etc on their surface Upon increasing the concentration of a particular cation i.e NH_4 or K+ or Ca++ in soil solution, as a result of its fertilizer application, it replaces the other cations in equivalent amount from the surface of soil colloids These released cations move down with irrigation water This interchange between cations in solution and another

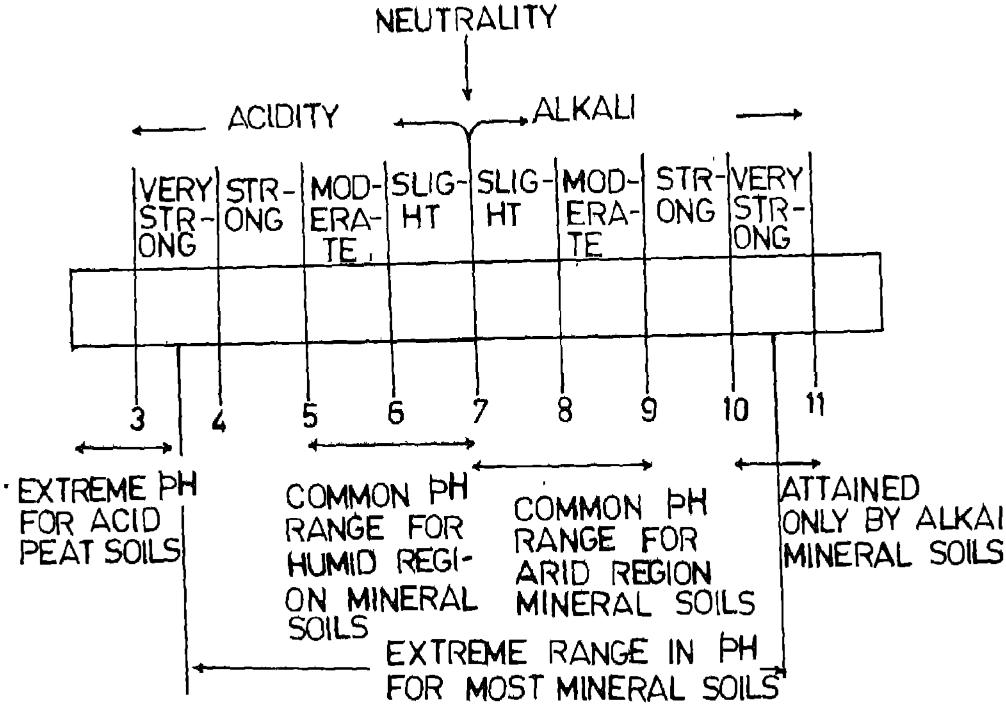

NEUTRALITY
ACIDITY
ALKALI
VERY STRONG
STRONG
MODERATE
SLIGHT
SLIGHT
MODERATE
STRONG
VERY STRONG
3
4
5
6
7
8
9
10
11
EXTREME PH FOR ACID PEAT SOILS
COMMON PH RANGE FOR HUMID REGION MINERAL SOILS
COMMON PH RANGE FOR ARID REGION MINERAL SOILS
ATTAINED ONLY BY ALKAI MINERAL SOILS
EXTREME RANGE IN PH FOR MOST MINERAL SOILS

Fig. 2.5 Range of Soil pH

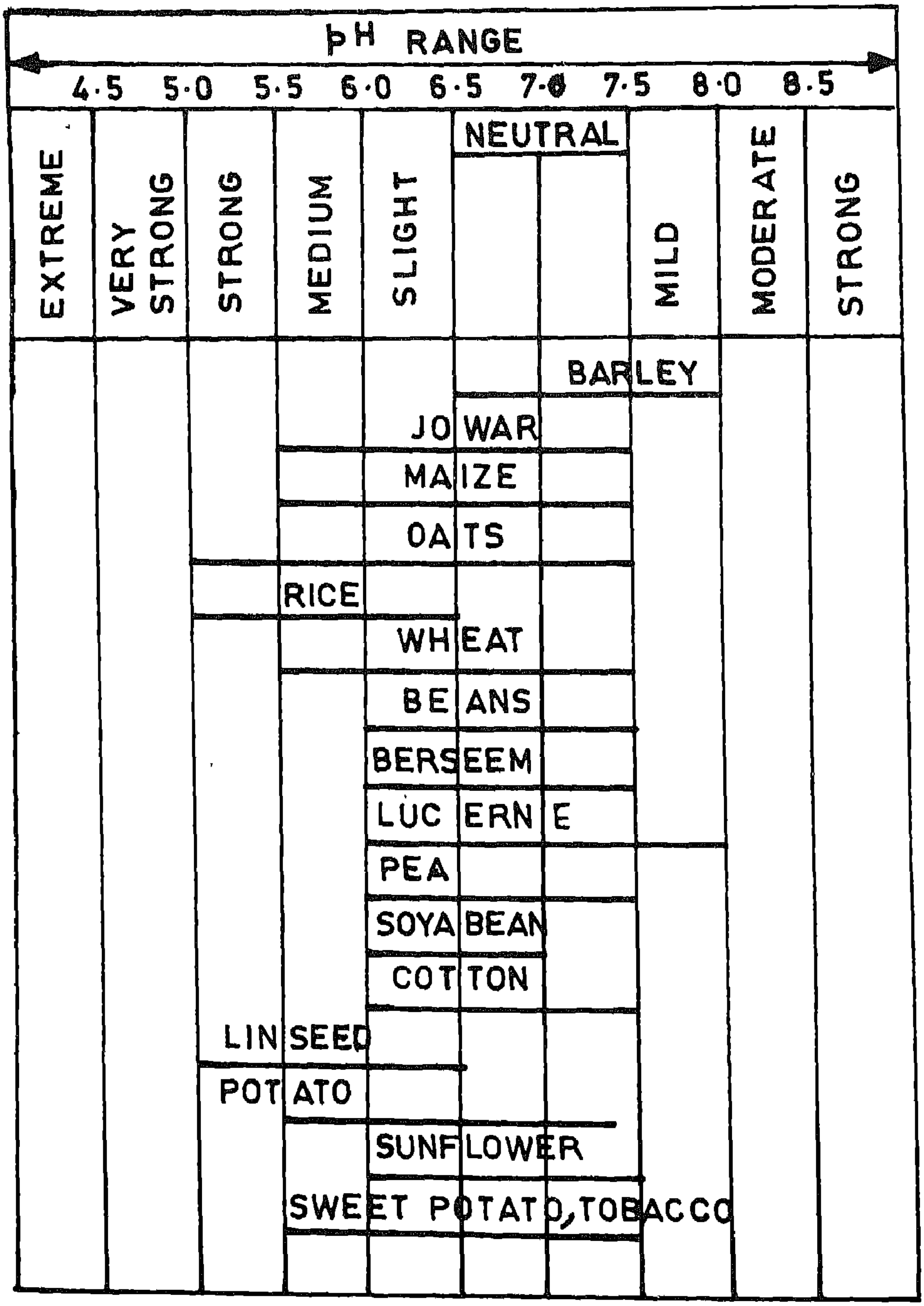


Fig. 2.6 Suitable pH for Different Crops

cation on colloid surface is called cation exchange as shown in Fig. 2.7.

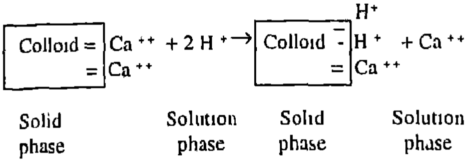


Fig. 2.7 Cation Exchange in Soil

The reaction takes place fairly rapidly and is interchangeable Cation exchange capacity may be defined as the sum of total exchangeable cations adsorbed by a soil, expressed in milli-equivalents per 100g soil. However, the sum of the exchangeable cations other than hydrogen is called base exchange capacity of soil It is expressed in per cent of cation exchange capacity. Cation exchange is most common and most important soil reaction. It finds application in nutrients retention, correction of soil acidity and reclamation of saline and sodic soils.

2.2.3 *Anion Exchange Capacity*

The replacement of anion between soil solution and colloid surface is called anion exchange. Soils rich in organic matter have less ability to hold anion than mineral soils Kaolinite clay containing soils have higher anion exchange capacity in comparison to those having illite or montmorillonite group of clay. The relative order of anion exchange is

$$OH^- > H_2PO_4^- > SO_4^- > NO_3^-$$

Among these anions, phosphate is the most important because in acid soils it is adsorbed with iron and aluminium of silicate clays which is replaceable. A large part of phosphate is precipitated with iron and alumina in acid soils and with calcium in alkaline soils. Sulphate and nitrate are not retained by soil particles in appreciable amounts for long period of time.

2.2.4 *Buffering of Soil*

Soils exhibit resistance to change in pH This resistance is called buffering of the soil. It is usually necessary to add much more acid or alkali than the amount required to neutralize H^+ or OH^- ions present in soil solution for changing soil pH.

Carbonate, bicarbonate and phosphate ions act as a buffering agent in the soil. Buffering capacity of the soil saves the plants from sudden change of climate and soil condition. However, there is always a need of larger amounts of lime or gypsum for correction of acidity or for reclamation of salt affected soils

2.2.5 *Salinization of Soil*

In arid and semi arid regions receiving low rainfall and high temperature, the soluble salts tend to accumulate on the surface. During rainy season, these salt leach down and come again on surface on continuous evaporation of water in dry season. Poor drainage keeps the salts on surface soil and prevents their leaching. Seepage in the canal increases the water table which accumulate the salts in the root zone. Soils developed on basic parent material also contain higher salt contents.

The higher salt concentration, specially sodium directly injures the plant roots and deteriorates the structure of soils making them infertile.

QUESTIONS

1 Differentiate between the following .
   (i) Soil texture and structure
   (ii) Particle density and bulk density of soil
   (iii) Soil plasticity and cohesion
   (iv) Soil saturation and field capacity.
   (v) Evaporation and transpiration of water
   (vi) Cation exchange and base exchange capacity of soil

2 How can you determine soil types by sense of feeling method?

3 Explain cation exchange capacity of soil with example

4. Fill in the blanks.
   (i) pH is a measure of__________and__________
   (ii) Clay particles have__________diameter in size.
   (iii) __________and__________type of soil structures are most favourable to plant growth
   (iv) Nitrogen fixing bacteria fix__________nitrogen.
   (v) High surface area is linked with__________of soil particle.

CHAPTER 3

Soil and Water Sampling

SOIL testing is a scientific method to examine the soil for its physico-chemical properties, nutrient status and other conditions which affect the crop growth and yield. It helps in proper planning for raising crops and management practices for maintaining good soil health and sustainable production To get the correct and precise information, soil sampling must be done properly

3.1 Soil Sampling

In general, the soil samples are taken for three purposes·

1. For fertilizer recommendation.
2. For reclamation of *Kallar* soil.
3. For plantation of orchards

3.1.1 Sampling for Fertilizer Recommendation

(i) *Sampling Tools* Tools required for soil samplings are *Khurpi, Tasla,* Auger, Cloth bag, *Sutli* and Copying pencil (Fig.3 1).

(ii) *Sampling Method*

1. Demarcate 8-10 spots in a field of 1-5 acres, on the basis of drainage, slope, soil type, cropping pattern and crop growth. Take separate sample for each spot and collect in a clean bag
2. Scrape away surface litter, if any
3. Take uniform core of soil from surface to plough depth (15 cm) by means of auger. If *Khurpi* or *Kassi* is used, dig a 'V' shape and hole up to plough depth and take a uniform slice of soil from top to bottom (Fig. 3.2)
4. In standing crop soil samples should be taken between rows of plants.
5. Sample should not be taken from fertilized soil and from roadside or from near the manure pits

(iii) *Mixing and Marking of Samples*

1. Mix well all the samples collected from different spots of a field and take a composite representative sample about 1/2 kg in a clean cloth bag.
2. Write the field number, name and address on two labels by copying pencil. One should be put inside the bag and another tied on the outside of the bag

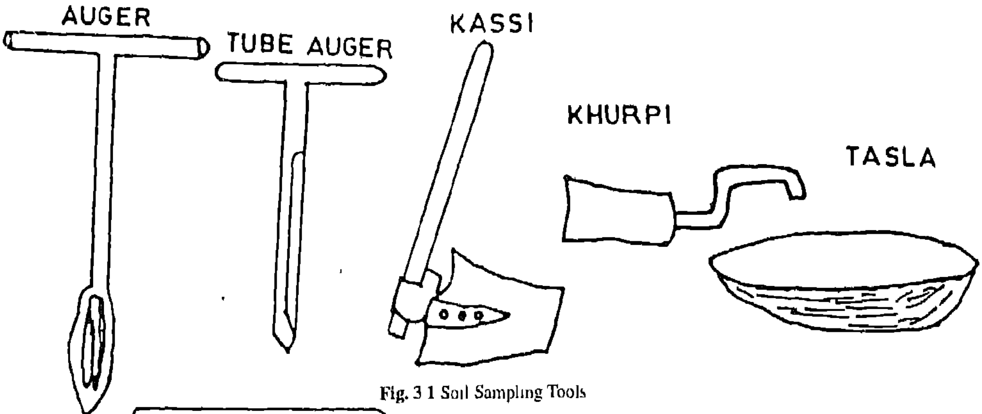


Fig. 3.1 Soil Sampling Tools

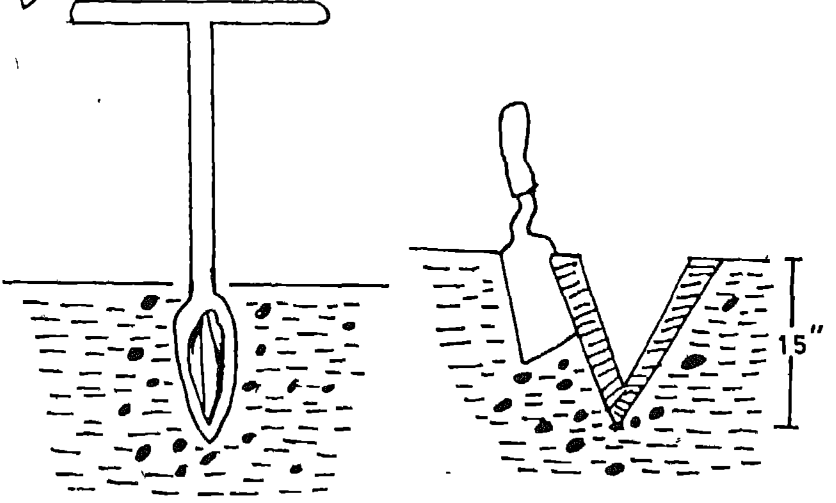


Fig 3.2 Soil Sampling by Augar and *Khurpi*

(iv) *Information Sheet*: Cropping history of the field should be filled carefully in the information sheet and sent to the nearest soil testing laboratory along with soil samples. This will help in making the report and the recommendation more useful. The information sheet should have the following information:

1 Number and name of field
2 Date of sampling.
3. Address of the owner of the field
4 Intended use and depth of soil sample.
5 Local name of soil
6 Type of land (irrigated or unirrigated).
7 Source of irrigation water and number of irrigations available
8 Natural drainage and depth of water table.
9. Probability of land to flooding
10. Slope of land (level, slopy undulated)
11. Rotation of crops being followed or to be followed
12 Details of manures or soil amendment applied.
13. Result of crop cutting experiment, if any
14. Any specific problem that a farmer has/had with his soil.

(v) *Frequency of Soil Testing* · The soil of a field under cultivation should be tested once in a crop rotation time. The frequency of getting soil tested should be more in case of light textured soils Soil samples may be collected anytime during a year but preferably when a crop has been harvested.

3.1.2 Sampling for Saline and Alkali Soils (Kallar Or Usar) Reclamation

Kallar soils are formed due to the movement of salt in soil with moisture, therefore, four samples are collected from the depth of 0-15, 15-30, 30-60 and 60-90 cm.

Soil samples can be taken for *Kallar* land by either using soil auger or by digging a 90 cm deep pit or profile. In case of pit, soil sample should be collected as described below and shown in Fig. 3.3

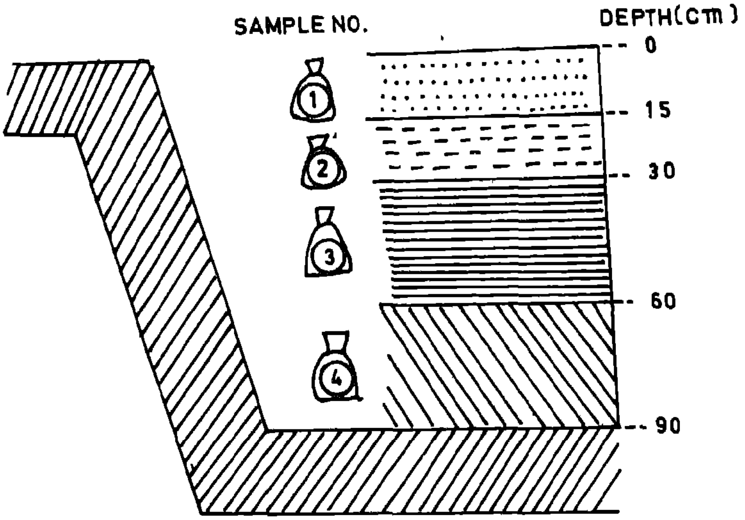


Fig. 3.3 Soil Sampling from a Profile for Kallar Reclamation

1. Dig a vertical pit upto 90 cm depth and mark at 15, 30, 60 and 90 cm on one vertical side
2. Hold the bucket at 15 cm mark and collect the sample by cutting uniform slice of soil from the top to 15 cm separately.
3. Similarly, collect the soil samples from 15-30, 30-60 and 60-90 cm mark.
4. In addition, a sample of surface crust should also be collected separately.
5. Each sample should be labelled carefully indicating field No. and depth of soil samples.
6. Each sample should be packed separately in clean cloth bag and sent to the nearest soil testing laboratory along with information sheet for recommendation.
7 Information sheet must contain .

(i) Nature of soil (visual observation).
(ii) Cause and source of salinity, if known.
(iii) Seasonal and annual rain fall.
(iv) Irrigation sources, frequency and history of irrigation.
(v) Depth of water table and natural drainage condition.
(vi) Crop rotation being followed or to be followed.
(vii) Soil management history.
(viii) Species and condition of plant cover.

3.1.3 Sampling for Garden Plantation

Since the nutritional status and physical conditions of the sub-soil are also important for fruit trees, the soil samples should be collected from the depth of 1.8 m (Fig. 3.4). Seven soil samples are collected separately from the depths of 0-15, 15-30, 30-60, 60-90, 90-120, 120-150 and 150-180 cm. If hard pan or concretion layer is found, its depth and thickness should be noted and a separate sample should be collected from the layer.

3.2 Water Sampling

Different underground water samples contain varying amount of salts depending on their area and all of them cannot be very successfully used for all crops on all types of soil. It would, therefore, be necessary to test their suitability for irrigation to a particular crop. These waters are classified into various classes according to chemical analysis (Table 3 1).

3.2.1 Method of Taking Water Sample

Take a clean bottle and rinse 2-3 times with water to be sampled. The samples are collected from running water pipe after running the tubewell for 20-30 minutes. The bottle should be properly sealed and record should be sent to soil testing laboratory along with the following information for recommendation:

1 Name of the farmer.
2. Location of the tubewell.
3. Depth of cavity if it is a cavity type tubewell
4. Discharge of tubewell.
5. Soil type on which irrigation is to be used.
6. Crop sequence to be followed.
7. Other source of water and amount of water available.

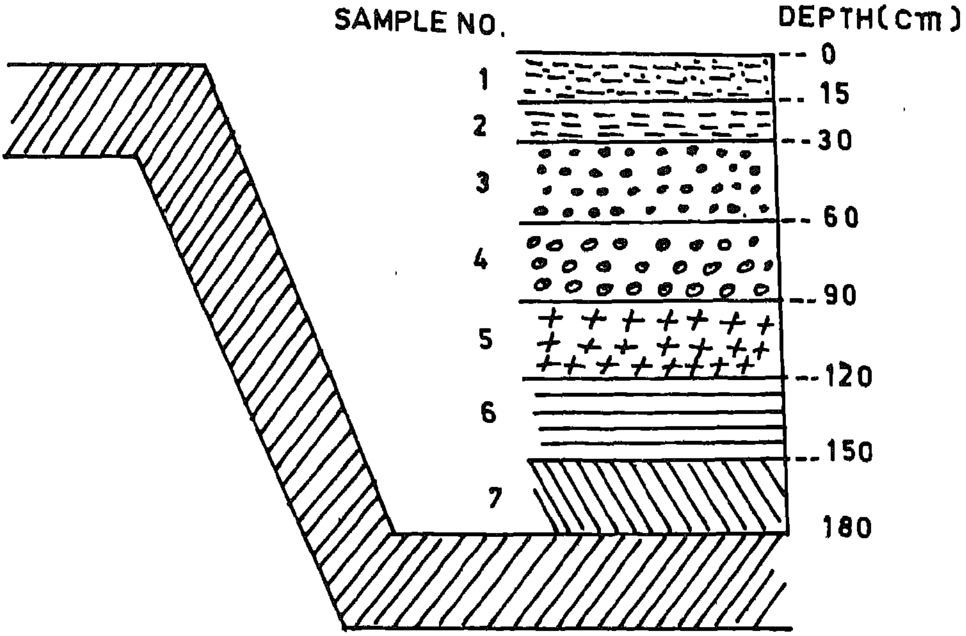


Fig. 3.4 Soil Sampling from a Profile for Garden Plantation

Table 3.1: Water Quality Classes Based on Chemical Analysis

Water Classes	*EC (ds/m)*	*SAR (m moles/l)$^{0.5}$*	*RSC (me/l)*	*Remarks*
A	<1.5	<10	< 2.5	Good, fit for all soil types and all crops
B	< 2.0	< 10	< 2.5	Normal, fit for all soil types and semi-tolerant crops.
C	2-4	< 10	< 2.5	Marginal saline, fit for loam soils and semi-tolerant crops.
D	4-8	< 10	Absent	Medium saline, fit for sandy loam and tolerant crops
E	8-12	< 10	Absent	Highly saline, fit for loamy sand and tolerant crops
F	12-16	< 10	Absent	Very high saline, needs heavy pre-irrigation, increase seed rate 20 per cent.
G	4-8	> 10	Absent	Saline sodic, mixed with canal water and tolerant crops.
H	< 4	> 10	> 2.5	Sodic, use gypsum and tolerant crops

EC – Electrical Conductivity, SAR - Sodium Absorption Ratio, RSC - Residual Sodium Carbonate, dS/m - deci Simon per meter, (m mole/l)$^{0.5}$ - millimole per litre underroot, me/l - milli equivalent per litre

Water test report furnishes the quality of water and its suitability for different crops as well as soils on the basis of their pH, electrical conductivity, sodium absorption ratio and residual sodium carbonate contents.

QUESTIONS

1 What are the purposes of soil sampling?
2. Write the detailed method of taking soil samples for fertilizer recommendations.
3. Whether the following statements are true or false .
    (i) Auger is a tool for taking soil samples
    (ii) Only one surface soil sample is collected for *Kallar* reclamation
    (iii) Underground water is always good for irrigation.
    (iv) Soil samples should be collected upto 1.8m depth of soil for fruit orchards plantation.
    (v) Soil samples should not be taken from standing crop.
4 Write short notes on the following .
    Information sheet,
    Auger,
    Water sampling,
    Soil testing and
    Soil sampling tools

●

CHAPTER 4

Soil Fertility and Productivity

THOUGH the terms soil fertility and soil productivity are often used synonymously, both have a distinct meaning. Soil fertility refers to the inherent capacity of soil to supply nutrients to plants in adequate amounts in suitable proportions The saline soil could otherwise be fertile but excess of sodium salt is toxic to plants Excess of sodium salt disturbs the availability of calcium, potassium and other nutrients. On the other hand, soil productivity is a broader term related to the ability of a soil to yield crops, whereas fertility is only one of the several factors that determine the magnitude of crop yields

4.1 Factors Affecting the Soil Productivity

The different factors which affect the soil productivity are divided into the following three broad groups.

1. Soil fertility management
2. Soil management practices.
3. Climatic factors

4.2 Soil Fertility Management

Plants require 16 essential nutrients for their normal development (Table 4.1).

Plants get C, H and O from the air along with water from soil for the

Table 4.1 : Essential Nutrients for Plants

Major Plant Nutrients	*Secondary Major Plant Nutrients*	*Micro-Nutrients*
Carbon (C)	Calcium (Ca)	Zinc (Zn)
Hydrogen (H)	Magnesium (Mg)	Iron (Fe)
Oxygen (O)	Sulphur (S)	Copper (Cu)
Nitrogen (N)		Manganese (Mn)
Phosphorus (P)		Molybdenum (Mo)
Potassium (K)		Boron (B)
		Chlorine (Cl)

photosynthesis and the other 13 nutrients from the soil Major plant nutrients are needed in higher quantity Secondary nutrients are required in slightly lower quantities than major nutrients. Micro-nutrients are required in very small quantities Nitrogen increases the growth of plants and makes them greenish. Phosphorus develops the grain and provides strength to the plant while potassium helps in developing taste and quality of grain or fruits Calcium maintains the turgidity of plant cells. Magnesium is the constituent of chlorophyll. Sulphur is required for synthesis of proteins Micro-nutrients are the constitutents of one or the other enzymes which regulate the metabolic activities, growth and reproduction process to complete lifecycle of plants The availability of plant nutrients depends on the following factors

4.2.1 *Soil Texture*

The soil texture is an almost permanent character depending upon the types of rock and size of soil particles Sandy soils are basically less fertile while silty and clayey soils have very high fertility because of their ability to retain almost all the nutrients due to their large surface area and high adsorptive capacity. Addition of organic matter can reduce the adverse effect of both sandy and clayey soils to some extent.

4.2.2 *Soil Structure*

Soil structure is the arrangement of soil particles and indirectly affects the availability of plant nutrients by regulating the moisture air regime, microbial activity and plant root action. The best structures for favourable physical properties of soil are crumby and granular (Fig 4.1). Both these types of structures could be encouraged by the incorporation of organic matter

4.2.3 *Colloidal Properties of Soil*

The soil particles which are less than 0 2 micron (µm) in diameter show colloidal

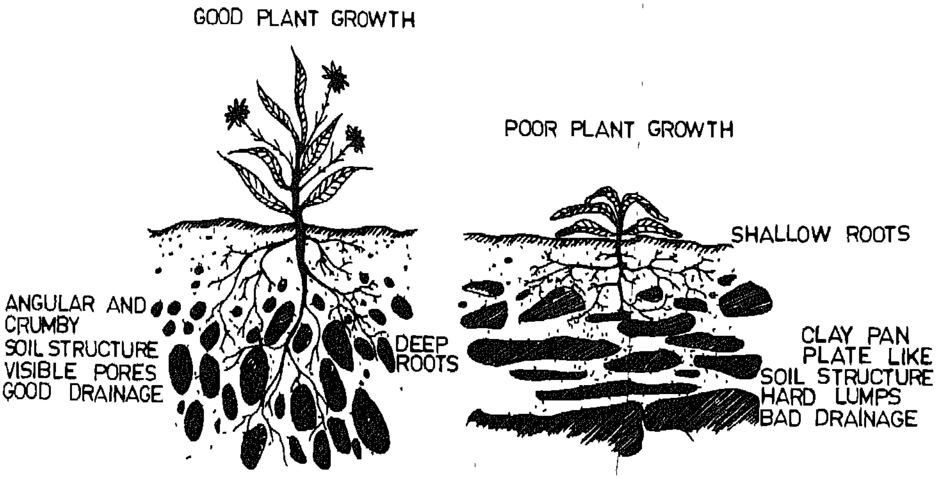

GOOD PLANT GROWTH
ANGULAR AND CRUMBY SOIL STRUCTURE VISIBLE PORES GOOD DRAINAGE
DEEP ROOTS
POOR PLANT GROWTH
SHALLOW ROOTS
CLAY PAN PLATE LIKE SOIL STRUCTURE HARD LUMPS BAD DRAINAGE

Fig. 4.1 Effect of Tilth on Soil Structure and Plant Growth

properties. Colloidal particles float in a medium and have very high chemical activity due to their large surface area and adsorptive capacity. Soils have two distinct types of colloids : mineral colloids (clays) and organic (humus) colloids. Both colloids have very intimate relationship and are bound together strongly to form stable crumbs with a great potential to hold plant nutrients and moisture

4.2.4 *Colloidal Clays*

The chemical nature of colloidal clays mainly depends on the type of minerals that compose the clays. These minerals fall into the following three main categories:

(i) *Kaolinite* : It is a two layer type of clay mineral. One sheet of silica oxide (SiO_2) is so tightly attached with another sheet of alumina oxide (Al_2O_3), which do not allow the entry of any cation or water molecule between them (Fig. 4.2). Therefore, Kaolinite type of clay mineral has a very low base exchange capacity resulting in acidic nature and little power to adsorb water and remains non-plastic even in moist condition. Lateritic soils containing kaolinite clay are acidic and have poor fertility.

(ii) *Illite* : It is a three layer type of clay. One alumina sheet is attached tightly with two silica sheets. Only potassium ions are snugly fit in silica sheet which do not allow the lattice to expand. Properties like hydration, adsorption, swelling, shrinkage and plasticity are intermediate of kaolinite and montmorillonite clays. Alluvial soils have generally medium fertility due to presence of illitic clays.

(iii) *Montmorillonite* : It has the same type of structure as in the case of illite but sheet can expand and allow the cations and water to exchange between two adjoining sheets (Fig 4.2). It has large surface area with very high adsorptive capacity of plant nutrients along with hydration, swelling and plastic nature. Black cotton soils of India are generally found rich in montmorillonite and have very high fertility.

Colloidal clays play a very important role in maintaining soil fertility in the following ways.

(i) Bind coarser soil particles and improve soil structure of sandy soils.

(ii) Retain plant nutrients against leaching and volatilization losses.

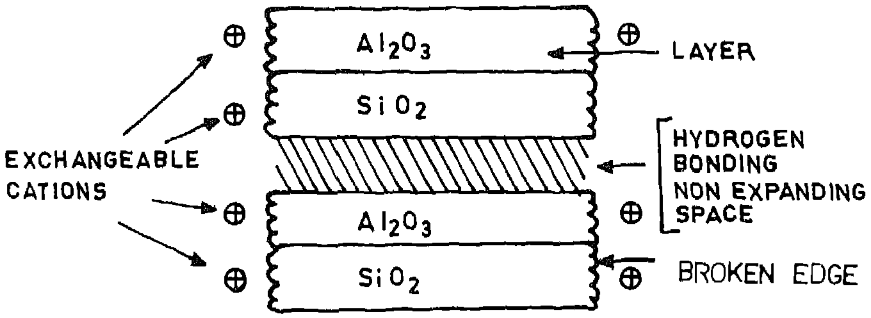
(iii) Ensure plant nutrients supply due to high cation exchange capacity.

(iv) Hold sufficient water for proper plant growth

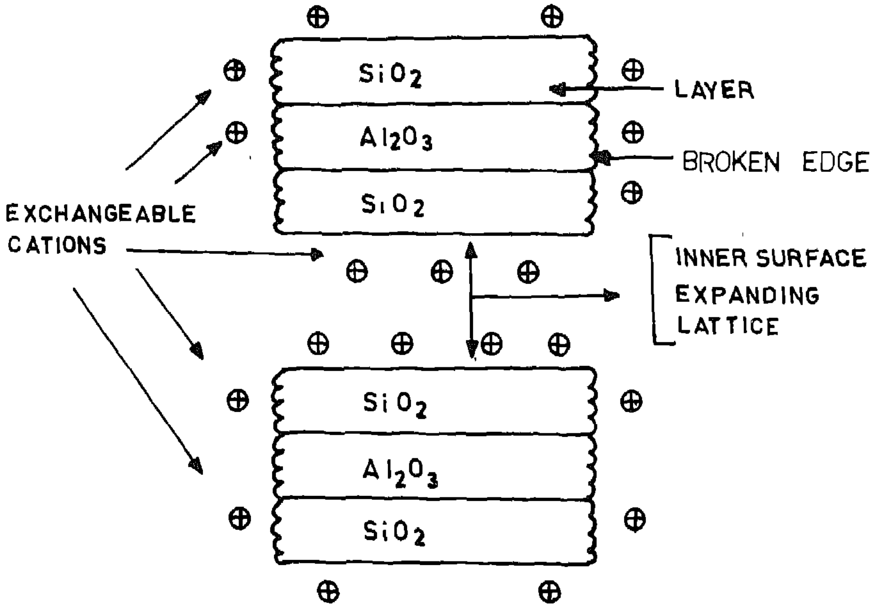
(v) Show buffering capacity against extreme warm in summer

4.2.5 *Colloidal Humus*

Organic matter in soil comes mainly from dead remains of plants, animals and animal manures. During decay of organic matter, microflora such as bacteria and fungi liberate carbon dioxide and form a substance called 'humus.' It is a formless black spongy, jelly like substance containing a wide range of complex life chemicals. Humus consists of lignin, protein and polyuronides (complex sugar plus uronic



1 KAOLINITE CLAY CRYSTAL



2. MONTMORILLONITE CLAY CRYSTAL

Fig. 4.2 Structural Diagram of Kaolinite and Montmorillonite Clays

acid). It releases soil nutrients and gasses on decomposition On weight basis, humus colloids have five to seven times higher adsorptive capacity for water and nutrients than clay colloids. Humus serves as ·

(i) A home for soil life

(ii) A store for well balanced food for the plant

(iii) Improves the structure of a wide range of soils.

(iv) Holds both air and water

(v) Warms the soil as its dark colour absorbs heat.

(vi) Mops up excess nutrients.

(vii) Stabilizes mineral soils.

(viii) Mops up toxic effect of heavy metals and pesticides

(ix) Protects soil from bad weather and soil erosion.

(x) Buffers the soil against pH changes

(xi) Stimulates plant growth by secreting growth promoting substances

4.2.6 Soil pH

Soil pH influences availability of plant nutreints and their absorption by plants. Most of the essential plant elements are available between the pH 6 5 to 7.5 (Fig. 4 3) However, molybdenum availability is higher at the higher pH levels. At pH value below 5.0, aluminium, iron and manganese often soluble in sufficient quantities but are toxic to plant growth At very high pH value, bicarbonates interfere with normal uptake of other nutrients and are detrimental to optimum growth of plants.

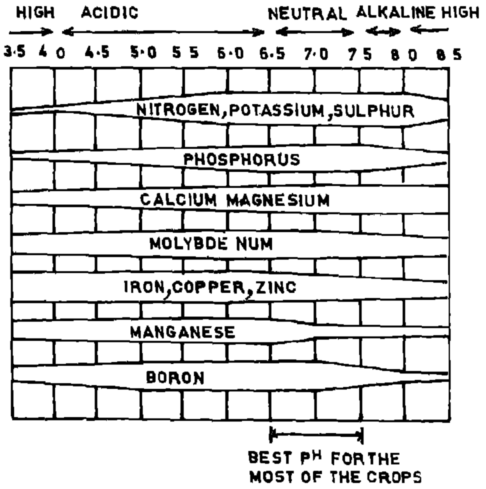


Fig. 4.3 Relation between pH and Relative Availability of Plant Nutrients

4.2.7 Soil Microbial Activity

Soil micro-organisms i e fauna (animal life) and flora (plant life), are dispensable in relation to crop production. They decompose organic matter and release essential plant nutrients held in organic combination. Slimy materials produced during organic matter decomposition improve the soil structure. Some microflora produce organic acids and humic substances which solubilize insoluble plant nutrients such as phosphorus, potassium, iron, manganese, etc. and make them available to the plant Two groups of bacteria: nodule bacteria (*Rhizobium spp.*) and free living bacteria (*Azotobacter spp.*) fix atmospheric gaseous nitrogen, a major plant nutrient and make it available to plants.

4.2.8 Soil Moisture

Proper moisture content in soil affects the availability and uptake of nutrients as plant roots absorb all the nutrients in solution form through osmotic and transpiration suctions (Fig 4 4) Excess water removes the plant nutrients through leaching or washes out from the surface. Sandy soils generally permit greater nutrient loss as compared to clays. The loss of phosphorus is negligible in all cases The leaching of nitrogen depends on crop growth and on the percolation of water. Calcium is lost in largest amounts and potassium least with percolation water

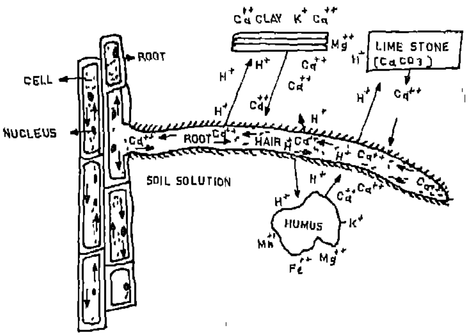


Fig 4.4 Root Hair Takes Nutrients from the Soil Solution

4.3 Soil Management Practices

The problems of soil management differ widely with the nature of soil and the species of crop to be grown, but there are some fundamental principles that govern the choice of soil management practices everywhere. Good soil management must be based on the factors given here.

4.3.1 Crop Rotation

Growing of crops in a fixed sequence is called crop rotation. Planting the same crop year after year deplete the plant nutrients in the soil in an unbalanced manner. Continuous cultivation of row crops encourages the loss of soil through sheet and gully erosion. A proper rotation of crops will control erosion or soil loss and preserve the soil productivity. A good rotation should include grain crops, millets, spreading pulse crops, legumes, deep and shallow rooted crops and low and high nutrient exhaustive crops.

Inclusion of *berseem* or any other legume crop in rotation increases the organic matter and nitrogen contents of soil Similarly, deep rooted crops like *arhar*, sugarcane, mustard take the nutrients from the lower part of the soil In Marathwada region, the yield of succeeding crop has been increased if groundnut is included in the normal cotton-*jowar* rotation The growing of pulse crop in kharif increases the yield of the cereal crop in rabi season than if the soil were kept fallow in the rainy season.

4.3.2 Selection and Balanced Use of Fertilizer and Manures

The continuous growing of high yielding variety crops in an intensive cropping sequence removes the nutrients in higher quantities and makes the soil deficient Therefore, the regular replenishment of plant nutrients through application of fertilizers and manures is necessary for sustainable crop production

(i) *Fertilizers* : These are chemical substances which supply one or more nutrients in concentrated form. The most commonly used fertilizers are nitrogenous, phosphatic and potassic, and some micro-nutrients like zinc sulphate. As fertilizer is a costly input, its amount should be determined on soil test basis. Most soluble and mobile nitrogenous fertilizer urea should be applied in two splits, half dose at the time of sowing and rest half at first irrigation Whereas, phosphatic and potassic fertilizers are less mobile and full dose of both should be placed at 4-5 cm depth below the seed at the time of sowing. In case of micro-nutrient fertilizers, they are sprayed only when plants show deficiency symptoms. Single super phosphate gives better responses in pulses and oils seed crops while the application of diammonium phosphate is nutrientwise cheaper and gives better responses to cereal crops.

If nitrogen, phosphorus, potash and zinc fertilizers are not applied in proper proportion, they will not give full performance. The utilizing efficiency of fertilizers can be increased by the application of organic manures.

(ii) *Manures* : These are well decomposed organic substances having low nutrient contents in organic combinations. They are prepared by decomposing lignocellulosic waste received from agricultural farm, industries and cities. Manures include farm yard manure (FYM), compost and green manure should be applied at least 20-30 days before sowing so that preliminary decompostion takes place before the seeds germinate. The application of undecomposed organic material reduces the crop yield. Organic manures containing humus improve the physico-chemical and biological properties of the soil.

(iii) *Bio-fertilizers* . These are the microbial strains which improve the fertility of the soil by fixing atmospheric nitrogen and solubilizing or mobilizing the nutrients essential for the growth of plants. They are available from Agricultural Universities and Regional bio-fertilizer centres established by the Central Government in different parts of the country. *Rhizobium* cultures are used in leguminous crops and *Azotobacter* culture in cereal crops.

4.3.3 *Soil Acidity*

The acid soils are generally found in humid regions where rainfall is high the soluble bases are carried away with drainage water and there is accumulation of acid residues composed of aluminium, silica and iron in the form of oxides. Acidity is also caused if soils develop on acid rocks. Soil acidity affects the plant growth in the following ways :

(i) Legumes do not nodulate below pH 5.7.

(ii) Soil bacteria become less effective.

(iii) Earthworms which improve the soil structure are generally found absent.

(iv) Toxic substances can be released in soil.

(v) The availability of some plant nutrients becomes low below pH 6.0.

(vi) Plant growth is generally reduced.

4.3.3.1 *Correction of Soil Acidity*

1. Add limestone, ($CaCO_3$) dolomite or burnt time as per recommendation (Table 4.2).
2. Use basic fertilizers such as calcium nitrate, basic slag and calcium cyanamide.
3. Grow acid tolerant crops like oat, sorghum, cowpea, maize, groundnut, potato, tomato, tobacco, watermelon, etc.

Table 4.2 : Limestone (q/ha) Requirements to Correct Soil Acidity

Soil pH	*Soil texture*		
	Sandy loam	*Loam*	*Clay loam*
5.0	11.25	16.87	26.25
5.2	9.75	14.62	22.75
5.4	8.25	12.37	19.25
5.6	6.75	10.12	15.75
5.8	5.25	7.87	12.25
6.0	3.75	5.62	8.75
6.2	2.25	3.37	5.25

4.3.4 Salt Affected Soils

The productivity of salt affected soils is very low. It can be improved by adopting the follwing practices :

(i) After levelling the field, the salt may be flush out or leach at down by heavy irrigation.

(ii) Add organic matter or practice green manuring

(iii) Grow salt tolerant crops such as *dhaincha*, paddy, *berseem*, barley, spinach, wheat, etc.

(iv) Gypsum should not be added to saline soil as it further increase its salinity

(v) Gypsum should be added to sodic soils only as per recommendation (Table 4.3) at the time of field preparation before sowing the crops.

The calcium ions of gypsum release the sodium ions (causes of sodicity) from exchange sites of soil particles. These sodium ions get leached down in the form of soluble sodium sulphate with irrigation water

Table 4.3 : Gypsum Requirement (tonnes/ha) for Reclamation of Sodic Soils

pH	*Soil texture*		
	Sandy soil	*Sandy loam*	*Loam soil*
9.0	–	Not needed	–
9.2	1.7	2.5	3.4
9.4	3.4	5.0	6.8
9.6	5.0	7.5	10.0
9.8	6.0	10.0	14.6
10.0	8.5	12.5	15.0
10.2 or more	10.0	15.0	15.0

$$\begin{array}{l}\text{Soil} \\ \text{Particle}\end{array}\begin{array}{l}Na^+ \\ Na^+\end{array} + \underset{\text{Gypsum}}{CaSO_4} \rightleftharpoons \underset{\text{Particle}}{\text{Soil}}\; Ca^{++} + \underset{\text{Soluble}}{Na_2SO_4}\downarrow$$

4.3.5 Irrigation and Drainage

Both irrigation and drainage are equally important to boost the agricultural production Irrigation is meant to arrange adequate moisture in soil for satisfactory growth of plant while drainage is necessary to avoid excess moisture from root zone. India has an ample supply of water in the form of rain or ground water but is not being utilized fully for our needs There is an urgent need to construct large dams including small reservoirs in watershed areas to harvest the rain water specially in monsoon season The loss of irrigation water can be minimized by constructing cemented channels and by adopting the suitable tillage, cropping system and sprinkler irrigation.

The collection of water either above or below ground surface should be avoided by having a surface or underground drains The different methods used in soil drainage are discussed in Chapter 8

4.3.6 Soil Erosion

The removal of soil surface from one place to another through wind or water is called soil erosion. In southern Haryana and Rajasthan, wind erosion is a serious problem. A lot of sandy surface soil is removed every year during summer months On the other hand, running water carries away the fertile top soil and declines the productivity of the land.

4 3.6 1 *Checking of Soil Erosion*

(i) On sloping lands or hilly region, strong bunds should be provided and strong forest trees planted

(ii) Contour farming should be adopted

(iii) The land should be kept under plant cover during the time when erosion hazard is the greatest

(iv) Provide wind breaks by planting Sesbania spp; eucalyptus, popular, etc trees against the commonly blowing winds

(v) Sow strips of row and cover crops alternatively on sloping lands.

(vi) Apply organic matter judiciously

4.4 Climatic Factors

Climate has a direct bearing on crop growth It also affects the farm work influencing soil productivity indirectly. The physico-chemical properties and nutrient supplying power of the soil are mainly dependent on parent materials and climatic factors such as rainfall, temperature sunshine and wind velocity.

Some farm practices like dry farming, strip cropping, storage of flood waters, contour cultivation, irrigation practices and planting of wind breaks help to combat the adverse effect of weather to some extent A sound knowledge of climatic factors and their effect on crop growth is, therefore, essential for maintaining soil productivity and profitable farming.

QUESTIONS

1 Define soil productivity How does it differ from soil fertility?

2. Classify the essential plant nutrients and write their source and functions.

3. Characterize kaolinite, illite and monomorillonite type of clays

4 Tick the correct answer

   (a) Clayey soils have high fertility because of their ability to .
      (i) Retain high moisture content
      (ii) Retain more plant nutrients
      (iii) Possess high surface area
      (iv) All the above three factors

   (b) Cracks develop in black soils due to
      (i) High organic matter
      (ii) Monmorillonite type of clay
      (iii) Illite type of clay
      (iv) High content of sand

   (c) Salt affected soils are reclamed by adding .
      (i) Lime
      (ii) Gypsum
      (iii) Sulphur
      (iv) Pressmud

   (d) Bio-fertilizers are
      (i) of biological origin
      (ii) chemical fertilizers
      (iii) organic manures
      (iv) soil amendments

5. Differentiate between the following .

   (i) Fertilizers and manures
   (ii) Humus and clays
   (iii) Soil acidity and alkalinity
   (iv) Water and wind erosion.

CHAPTER 5

Soil Tilth and Tillage

DURING ancient times, man used to roam around in search of food Centuries later, he planted fruits and food crops, and grazed animals In the process, he experienced that scratching and keeping weed free land enhanced the crop yield Now-a-days the importance of tilth and tillage of soil is well-established Some implements from hand pulling to bullock drawn ploughs, tractor drawn steel ploughs and cultivators are being used for various tillage operation.

5.1 Soil Tilth

Soil tilth is generally defined as the physical condition of the soil in its relation to plant growth. These soil conditions include ready infiltration of rainfall, sufficient moisture, adequate aeration and favourable soil temperature. This means that tilth is related to the size distribution of the soil aggregate and their arrangement which give rise to good soil structure. It can be achieved by adopting appropriate method of tillage, cropping system and by application of manures, fertilizers and some suitable soil conditioners It is a dynamic soil condition and tends to deteriorate under the usual cropping and tillage operations

5.2 Soil Tillage

The scraping or digging of soil to improve the soil structure conducive to good yield is called soil tillage. It is one method which is generally used to improve the soil tilth. The basic purpose is to provide the best physical conditions of soil for optimum plant growth and to control the weed and soil born diseases, insect and pests. Tillage operations include the following .

Deep ploughing
Ploughing
Harrowing
Planking

5.2.1 Deep Ploughing

Deep ploughing is generally given to break the clay pan and improve the structure of sub-soil for better and deep penetration of the plant roots.

5.2.2 Ploughing

The mechanical functions of the plough consist of the cutting, loose, granulation and inversion of the furrow slice of the soil.

5.2.3 Harrowing

Harrowing is the mechanical function used for breaking the clods on ploughed land. It is generally used in heavy soils, grass prone fields and mould ploughed fields

5.2.4 Planking

The smoothening of the loose soil through heavy wooden log to give desired compactness of upper surface of seedbed is called planking. It is done to make the surface even, crush the clod and check the moisture loss during tillage operation specially before sowing the seeds.

5.3 Seedbed or Rootbed Preparation

Seedbed is usually considered the ploughed layer of soil which has been so prepared that planted seeds will readily germinate and the young plants will have a satisfactory conditions for root development and growth This emphasises the importance of preparing a few surface inches of soil so that the seed will germinate and emerge. Soil profile structural qualities are important for effective growth after emergence. The so-called seedbed functions for only a week or 10 days, therefore, rootbed would be a much more appropriate term since it would refer to a favourable structure not only for germination and emergence but also for the complete development of the plant

Good seedbed or rootbed should fulfil the following requirements :

(i) Permit the rapid infiltration and satisfactory retention of usable rainfall.

(ii) Afford an adequate air capacity and a ready exchange of soil air with the atmosphere

(iii) Offer little resistance to root penetration

(iv) Resist erosion

The lower part of an ideal seedbed should contain the finest granules possessing firmest degree of seedlings. The coarseness or granules increase as one approaches the surface The ideal type of seedbed aims at keeping the soil receptive to rainfall and favourable to air exchange.

5.4 Kinds of Tillage

The stable granular structural condition of the soil which is a primary pre-requisite for obtaining good tilth in seedbed, must be produced before ploughing.

5.4.1 Normal Tillage

Ploughing is generally, the first operation in the preparation of a seedbed. The success of the ploughing operation in obtaining good granulation of the furrow slice depends primarily upon the granular nature of the soil and moisture content at which the soil is ploughed. There is an optimum range of soil moisture for each soil type that permits effective results in ploughing.

5.4.2 Minimum Tillage

This refers to the planting of row crops in ploughing land with no seedbed preparation except in the row where the seed is placed.

5.4.3 Zero Tillage

The advent of chemical herbicides has made it possible to kill plants in sods without having to turn them under with a plough This has stimulated interest in planting corn with zero tillage with special grassland corn planters.

5.4.4 Mulching

Mulching is a loose covering on the surface of the soil which usually consists of organic residues It is a system of management of crop residues that uses sub-surface tillage by sweeping to loose the soil and at the same time leaving the residues on the surface for erosion control. Inter-culturing operations kill weeds and reduce moisture evaporation loss from top soil. Inter-culturing also breaks the surface crust formed after rain and facilitates the seedling emergence particularly in case of *bajra, cotton* and *raya* crops

5.4.5 Cultivation

The maintenance of good tilth through cultivation during the growing season is of special importance. Since it regulates the water and air regimes of the soil. Rapid infiltration of rainfall and adequate aeration are the two most significant reasons for cultivating crops

Crusting of soil surface under the impact of falling raindrops reduces infiltration and impedes aeration. Sub-surface compaction is caused by the use of heavy machinery which also restricts water infiltration and adequate aeration Cultivation increases the infiltration rates of crusted and compacted soil and increases the normal aeration of the root zone Air supply to plant roots as well as to soil micro-organisms is greatly augmented and this increases the productivity of soil. In high permeable soils sub-surface compaction with passes of a heavy roller (1.5 ton) over the surface has been found to increase the yield of several crops by reducing water and nitrogen losses and increasing moisture retention in the root zone Puddling is necessary to reduce deep percolation loss in paddy cultivation

5.5 Effect of Cropping System on Soil Tilth

The restoration of stable granulation in soil is a relatively slow process. Cropping systems play a significant role in soil aggregation primarily through the impact of the granulating effects of root systems, protective influence of vegetative canopies and the production or organic materials that promote biological activity Crop rotations have been most effective in promoting and maintaining good soil structure A good crop rotation includes.

- Deep rooting and shallow rooting crops which absorb the nutrients and water from different depths of soil
- Crops which do not cover soil totally are alternated with ones which do (e g potato) to protect soil moisture
- Hungry crops such as brassicas are followed by crops which feed less of the soil.
- Green manuring crops.
- Legume crops

5.6 Effect of Lime, Gypsum, Manures and Fertilizers

Lime treatment of acid soils promotes greater development of vegetation and production of organic matter, which usually causes a regeneration of structure. Similarly, the application of the gypsum in sodic soil improves the soil structure.

Applications of organic matter either in the form of Farmyard Manure (FYM) or compost or green manure have produced varying results on improving soil structure.

Humus and other gluing compounds produced during organic matter decomposition improve the soil structure and increase the water and nutrient retention capacity of the soil

Large application of sodium salts causes deterioration of soil structure Phosphorus application decreases soil strength and increase water holding capacity by better soil aggregation. Increased foliage and root production as a fertilizer application have a great influence on the preservation and partial restoration of soil structure. The high application of potash is an effective control for the wilting disease of cotton

QUESTIONS

1 Define soil tilth. How does it differ from soil tillage?
2. Write short notes on the following:
   Mulching, normal tillage, zero tillage, and inter-culture
3 Explain seedbed preparation
4 Distinguish between the following:
   (i) Minimum tillage and zero tillage
   (ii) Lime and gypsum
   (iii) Zero tillage and normal tillage.
5. How does crop rotation maintain good soil structure?

CHAPTER 6

Forage Crops and Their Production

LIVESTOCK production, an important occupation of farmers, plays a vital role in agricultural economy of India. But the low productivity of our livestock is a matter of great concern which is mainly due to non-availability of required quantity and quality of fodder There is a chronic shortage of feed and fodder. Moreover, the forage produced is of poor nutritive value The present deficiency in total forage requirement is about 53 per cent of dry fodder and 68 per cent of green forage. This gap in forage production can be filled up only through the use of latest varieties and production technology of various forage crops.

6.1 Definition of Forage and Fodder

The word "forage" includes a wide range of feeds such as cereal fodder, cultivated and uncultivated grasses and legumes, shrubs and trees which can be utilized for feeding animals. The cultivated forage crops are called as fodders.

6.2 Importance of Forage Crops

Producing and supplying feed and fodder for dairy cows/buffaloes is one of the farmer's important responsibilities. It is professed that the country's milk production could be doubled if the dairy animals were adequately fed The role and importance of forage crops are :

1. Provide fodder and feed to the livestock which accounts for about 60 per cent cost of their milk production.
2. Make available fibrous material for microbial activity in the animal system and to meet the energy requirement.
3. Forage gives sense of repletion to the ruminants and aids in easy expulsion of dung. Fresh forage acts as a laxative.
4. Provides vitamins and other minerals required for the animals
5. Fodder crops can be produced in short periods and hence these fit well in various cropping patterns.
6. Grown in closer spacing with dense stand, forage crops smother weeds and prevent soil erosion.
7. High persistency and regeneration reduce the need for frequent tillage and sowings, etc.
8. Forage crops, in general, have wider adaptability to problematic and adverse conditions

9 These are complimentary to enable farming, provide sustainability to agricultural production and are economical in production.

6.3 Classification of Forage Crops

Forage crops can be classified according to their period of production:

I. Annual Forage Crops

1. Cereal cultivated fodders·
   (i) Kharif (Monsoon) season: *Jowar*, Maize, Teosinte and *Bajra*
   (ii) Rabi: Oats.
2. Legume cultivated fodders.
   (i) Kharif (Monsoon) season. *Guar* and Cowpea.
   (ii) Rabi (Winter) season: *Berseem*, Lucerne and *Brassica* sp.

II Perennial Forage Crops

1. Pasture and other grasses Napier, Guinea, Signal, Rhodes, Buffel grass
2. Legumes : American Joint Vetch, Roundleaf cassia, Verginianum, Centro, Glycine, Siratro and Stylo.

III. Top-Feed Species

Subabul, *Khejri* and *Sesbania sp.*

6.4 Cultivated Cereal Fodders

The main cereal fodder crops are *jowar*, maize, teosinte and oat grown widely for forage purposes. These are high yielding and better in most of the quality traits

6.4.1 Sorghum/Jowar (Sorghum bicolor)

Jowar is the most important food and fodder crop of dryland areas of India. It is widely grown for grains in states like Maharashtra, Andhra Pradesh, Karnataka, Madhya Pradesh. Tamil Nadu and Gujarat. But in northern states viz. Punjab, Haryana, Delhi, Western U.P. and in some parts of Gujarat and Rajasthan it is exclusively grown for fodder purposes It is one of the most important forage crops occupying about 80-90 per cent of acreage under fodder crops during summer and monsoon seasons. It is very hardy and widely adapted to adverse climatic conditions and offers great potential for supplementing the fodder resources of the country. Its fodder contains 5-9 per cent protein, 30-32 per cent fibre, 48-50 per cent neutral detergent fibre (NDF), 1.5 to 2.5 per cent ether extract, 0 3 to 0.5 per cent Ca, 0.2 to 0 4 per cent phosphorus, 50-60 per cent total digestible nutrients (TDN), 2 to 5 per cent digestible crude protein (DGP) and 50 to 60 per cent dry matter digestibility (DMD) Varieties like *M P. Chari, HC 136, HC 171, PC 6* and *U.P. Chari-2*, for single cut and *Methi Sudan (SSG 59-3), PC 23, SG 988, MFSH-4, Hara Sona* for multicut are most popular and widely grown for fodder in our country.

6.4 1.1 Soil and Its Preparation

Sorghum crop can be grown on all kinds of soils except highly alkaline or saline soils which cause drastic reduction in its germination. But loam, sandy loam and medium deep black soils with proper drainage are predominantly suitable for growing forage sorghum In general 2-3 harrowing followed by planking are sufficient to prepare most of the soils for sowing *jowar* for fodder.

6 4 1.2 Sowing Time, Seed Rate and Method of Sowing

Sowing time of *jowar* depends upon soil temperature, weather factors and cutting system. In most of the *jowar* growing regions of the country, *jowar* for fodder is sown during summer and monsoon seasons Under unirrigated condition *jowar* for fodder should be sown immediately after first shower but in areas with irrigation, forage sorghum should be sown from 15 to 30th June for single cut and from first week of April to mid May for multicut after giving pre-sowing irrigation to the field In the south, the rabi season sorghum for fodder should be sown from end of September to October.

A seed rate of 40-50 kg/ha for bold seeded varieties and 20-25 kg/ha for small seeded varieties is the best for getting good yield and thin stemmed crop. Forage sorghum is sown in lines by seed drill or by *kera* (placing the seed by hand in furrows) or *pora* (placing the seeds by iron or bamboo pipe) method using bullock drawn plough having a distance of 25-30 cm between lines but seed should not go deeper than four cm

6 4 1.3 Fertilizers

Nitrogenous fertilizer is most beneficial for high yield and better quality of fodder in sorghum. In irrigated or high rainfall areas, application of 80 kg N/ha is most optimum, while in unirrigated areas, 40 kg N/ha should be applied in case of single cut varieties However, if sorghum is grown after some leguminous crop then nitrogen should be reduced by 40 per cent. Half dose should be applied before sowing and remaining half should be applied after 35 days of sowing If soils are deficient in phosphorous and potash then 30 to 40 kg P_2O_5/ha and 25-30 kg K_2O/ha should be applied based on soil test at the time of field preparation In multicut sorghum, 100-120 kg N/ha is recommended. If three cuttings in a variety are to be taken then half nitrogen dose should be applied before sowing and remaining half be applied in two equal doses i.e. after first cut and second cut which will ensure proper regeneration, faster growth and higher fodder yield in the crop If there is zinc deficiency in the soil, $ZnSO_4$ at the rate of 5 kg/ha may be applied in the field before sowing

6 4 1 4 Irrigation and Weed Control

Sorghum crop sown after pre-sowing irrigation in June will need one or two irrigations Summer season crop sown from April to May should be given 3-4 irrigations at 10-15 days interval. In multicut sorghums, irrigation should invariably be given after each cut for better regeneration and faster growth, otherwise, the crop is adversely affected

Problem of weeds in sorghum is most serious in rainy season. Proper and timely control of weeds is necessary up to one month of sowing of the crop. For this, one or two weedings should be done after 15-20 days of the sowing of the crop. Control of weeds can also be done by the spraying a chemical weedicide, Atrazine at the rate of 0 5 kg Active Ingredient (a i)/ ha in 500 litres of water just after sowing of the field when its upper surface is moist

6.4.1.5 Harvesting and Fodder Yield

Hydrocyanic acid (HCN) is a major toxic compound found in most of the varieties of sorghum during their crop growth. It causes poisoning to the animals if sorghum fodder is fed to them in early stages of the crop Sorghum crop has higher content of HCN at early stages and it decreases with the advancement of crop growth. Various factors like varieties, age of the crop, soil moisture and kind of fertilizers affect the HCN content in sorghum. HCN content is higher upto 35-40 days of crop growth and toxic limit of HCN is above 200 ppm which decreases after the above period and at flowering every variety has safe limit of HCN Harvesting of sorghum for fodder should be done keeping the above factors in view

Single cut varieties should be harvested at fifty to full flowering state in order to get maximum fodder yield with better quality. In case of early, medium and late flowering varieties, this stage comes at 60, 75 and 90 days of sowing of the crop, respectively. In case of multicut varieties, first cut should be taken at boot stage or 55-60 days after sowing. Subsequent cutting can be taken at an interval of 35-40 days after the previous cutting. Maximum 3-4 cuttings can be taken from a multicut variety Harvesting should be done at 5-8 cm stubble height in single cut and 10-15 cm height in case of multicut varieties. Single cut varieties yield 400-550 quintals green fodder per hectare, while multicut varieties give 700-800 quintals of green fodder per hectare.

6.4.2 Maize (Zea mays)

Maize, locally known as *Makka,* is a nutritious, palatable and succulent cereal fodder crop grown during summer and kharif seasons in the north while it is grown throughout the year in southern India. It is an excellent fodder most suitable for conservation as silage. It originated in central America and is grown in a number of countries of the world. In India, it is grown extensively for fodder in the states of Jammu and Kashmir, Punjab, Haryana, Himachal Pradesh, Uttar Pradesh, Madhya Pradesh, Bihar and Rajasthan Varieties, African Tall and Vijay composite are recommended for cultivation for fodder.

6.4.2.1 Soil and its Preparation

Maize requires well drained loam and fertile soil for good growth It can be grown from moderately acid to moderately alkaline soils provided there is no deficiency of micro nutrients Field should be harrowed before pre-sowing irrigation and two criss-cross ploughings followed by planking are enough for better germination and growth.

6.4.2.2 Sowing Time, Seed Rate and Method of Sowing

Maize can be sown any time from early March to 15th of September. However, in summer sowing (May-June), the crop growth is hindered due to high temperature. Generally, maize is sown for fodder in early March to April and from August to September as it does better than sorghum during those periods

Seed rate varies with type of soil, season and seed size, etc. Varieties with bold seed need 20 per cent more seed rate while varieties with small seed need 20 per cent less seed for sowing Normally, 75 kg seed/ha gives enough plant stand for good fodder yield To get good quality forage, maize should be sown mixed with cowpea, in 2·1 ratio i.e. two rows of maize and one row of cowpea In mixed cropping, the seed of maize should be sown at 50 kg/ha and cowpea seed at 12 kg/ha. The sowing of maize may be done preferably by *pora* or *kera* method in rows at 25-30 cm spacing

6.4 2 3 Fertilizers

Being a very fast growing cereal fodder, it responds well to higher fertility Depending upon soil type and nutrient availability, 60-75 kg N/ha should be applied in two split doses i e. half before sowing and another half at 30 to 35 days after sowing.

6.4 2 4 *Irrigation and Weed Control*

Maize is sensitive to both drought and water stagnation but needs good moisture for better growth. First irrigation should be given at 20-25 days after sowing Successive irrigations at 10-12 days interval in summer and 15-20 days interval during early summer and in September should be applied

It is fast growing crop and hence do not allow the weeds to compete But, one hoeing should be done after first irrigation to control weeds and for good growth of the crop For chemical control of weeds. Atrazine at 0.5 kg a i./ha in 500 litres of water should be sprayed uniformly at germination of the crop.

6 4 2 5 Harvesting and Fodder Yield

For getting good quality fodder, maize should be harvested from silk to milk stage otherwise palatability and digestibility of fodder will decrease drastically after this stage. Fodder yield varies from 350 to 500 q/ha depending upon variety, soil fertility, stage of harvest and season, etc

*6.4.3 **Teosinte (Euchlaena mexicana)***

Teosinte locally known as *Makchari* is believed to have originated in Mexico and introduced in India from Latin America. It is generally grown in warm and moist regions particularly in countries like America, Philippines, Indonesia, Japan, Myanmar, India, Australia, Malaysia, Columbia and Argentina It is highly leafy, palatable and nutritive cereal fodder grown during summer and kharif seasons. Unlike maize, it tillers profusely with slow growth in early stages It is almost free from insects pests and diseases It has tolerance to water stagnation as compared to other kharif fodders Only one variety of this crop, improved Teosinte is recommended for fodder in our country.

6 4 3 1 Soil and Its Preparation

Loam to clay loam soils with good moisture retention capacity are good. Saline, alkaline, sandy and shallow soils are not good for its cultivation A deep ploughing followed by two cris-cross harrowing and planking are enough to produce a fine seed bed.

6.4 3 2 Sowing Time, Seed Rate and Sowing Method

Teosinte is sown from early March to end of September in the North while in the South sowings in June, July, September and October are preferred Crop should be sown by seed-drill or *pora* or *kera* method in rows 30 cm apart for higher fodder yield as compared to broadcasting In clay soils (paddy soils) broadcasting of the seeds and then mixing it with soil by ploughing should be adopted Fully mature brown to chocolate coloured 40 kg seed/ha is enough for getting proper plant stand.

6.4.3.3 Fertilizers

A well rotted 25 tonnes of farmyard manure (FYM) per hectare is enough if applied before pre-sowing irrigation If farmyard manure (FYM) is not available, apply 30 kg N 25 kg each of P_2O_5 and k_2O per hectare in the field at the time of sowing and 30 kg N/ha should also be applied after first irrigation.

6.4.3.4 Irrigation and Weed Control

The crop should be irrigated at 12-15 days interval in peak summer and 15-20 days interval during September and October During rainy season irrigation should be applied as and when required depending upon rains

In case of fields with heavy infestation of weeds one pre-germination spray of Atrazine at 0 5 kg active ingredient/ ha in 500 litre water helps to check the problem of weeds Weed can also be controlled by one hand weeding after first irrigation

6.4.3.5 Harvesting and Fodder Yield

The best stage for the harvest of this crop is 5-10 days before tasseling which gives good yield of fodder with higher digestibility Beyond this stage, crop turns fibrous and loose palatability and digestibility. Early and late sown crop gives 250-300 q/ha green fodder, while normal sown crop gives 400-450 q/ha green fodder.

6.4.4 Oats (Avena sativa)

Oat locally known as *Javi* is grown in irrigated areas of semi-arid regions Cool and comparatively moist weather conditions are most favourable for its proper growth. Oats can be grown under limited irrigation It is a highly palatable and nutritive cereal fodder mostly recommended for feeding to dairy animals and horses Oats fodder can be converted into hay or silage for feeding livestock in lean periods. Oat is cultivated in several foreign countries and in India it is grown in states like Jammu and Kashmir, Punjab, Himachal Pradesh, Uttar Pradesh, Haryana, Rajasthan, Madhya Pradesh, Gujarat, Maharashtra and West Bengal. Varieties like *Kent, HFO-114, OS-6, OS-7, UPO-94, OL-9, JHO 822* and *JHO 829* of oat are widely grown in our country.

6.4.4.1 Soil and its Preparation

Medium fertility soils are best for its cultivation as heavy soils with high fertility result in the lodging of the crop It can also be grown on acidic or alkaline soils One harrowing before pre-sowing irrigation and two criss-cross ploughings followed by planking are enough to raise the oat crop for fodder

6.4.4 2 Sowing Time, Seed Rate and Method of Sowing

The first fortnight of October is the best sowing time for multicut varieties. Single cut varieties should be sown from mid October to end of November, 75 kg seed for small seeded varieties and 100 kg seed for bold seeded varieties per hectare is needed. Sowing should be done by seed-drill or *pora* method in rows at a distance of 25-30 cm and then planking should be done to conserve the moisture for good germination of the seed

6.4.4.3 Fertilizers

In soils deficient in zinc, apply 20 kg $ZnSO_4$/ha before sowing. 40 kg N/ha before sowing and 30 kg N/ha at 30 days after sowing may be applied in case of single cut and additional 30 kg N/ha after each cut in multicut varieties for obtaining higher fodder yield in oat.

6.4.4.4 *Irrigation and Weed Control*

A deep irrigation should be given for better preparation of soil before sowing as it is very necessary for good germination in early sown crop First irrigation at 30-35 days after sowing and subsequent irrigations at 20-25 days interval may be given. In case of multicut varieties, one irrigation immediately after harvesting the crop for fodder is necessary for better regeneration, tillering and faster growth One hoeing with *Kasola* after first irrigation is enough to control the weeds

6.4.4.5 Harvesting and Fodder Yield

First cut in multicut varieties should be taken between 60-65 days after sowing and the second cut can be taken at 50 per cent flowering at 5-7 cm above the ground level to ensure better regeneration. Green fodder yield from two cuts will be about 600 q/ha. Single cut varieties yield 450-500 quintals green fodder per hectare and these should be harvested at 50 per cent flowering Harvesting before flowering results in less fodder yield and over maturity reduces palatability and digestibility of fodder.

6.5 Cultivated Legume Fodders

All the cultivated legumes are highly nutritious and are grown as pure and mixed cropping.

6.5.1 Cowpea/Lobia (Vigna unguiculata)

Cowpea is a warm season annual leguminous fodder crop grown mainly in Northern and Central India It is generally grown in mixture with *jowar, bajra* or maize to enhance the green fodder yield and to supplement their nutritive value It can be fed green, converted into good quality hay or conserved in the form of silage when mixed with cereal fodders, *HFC 42-1, Cowpea-74, Russian Giant, EC 4216, UPC 5287, UPC 5286,* and *IGFRI S-450* are recommended varieties of cowpea for fodder

6.5.5.1 Soil and Its Preparation

Cowpea can be grown successfully on a wide range of well drained soils with moderate to high fertility except on those soils which are too sandy. Two to three criss-cross harrowings followed by planking are sufficient to make the soil fit for sowing. It cannot withstand high salinity, alkalinity and waterlogging.

6.5.1.2 Sowing Time, Seed Rate and Method of Sowing

The sowing period of the crop for green fodder extends from mid March to mid July, however, it can be sown up to end of August. In South India, it can be grown throughout the year if pest and diseases are properly controlled.

The seed should be sown by *pora* method during summer and *pora* or *kera* method during kharif season. Sowing should be done in lines 30 cm apart using 40 kg seed/ha. When cowpea is sown in mixture its seed rate should be one-third Seed should be inoculated with *Rhizobium* bacteria for vigorous growth.

6.5.1.3 Fertilizers

Fertilizers should be applied according to soil test. Application of 25 kg N and 60 kg P_2O_4/ha at the time of ploughing of the field is normally done. Initial nitrogen is applied to give better start to the crop and fulfill the N requirement till the nodules are formed particularly if soil is poor in nitrogen. Phosphorus application helps in root development and microbial activity for increased absorption of mineral salts In case of inter cropping with maize, *jowar* or *bajra,* dose of fertilizers should be adjusted in proportionate to the requirement of these crops

6.5 1.4 Irrigation and Weed Control

The first irrigation may be given 15-20 days after sowing but the subsequent irrigations should be applied at 10-15 days interval during summer months. In rainy season, the irrigation interval depends upon the rainfall and its distribution. During the post monsoon season, 3 to 4 irrigations are sufficient.

During rainy season weeds infestation is severe and it should be controlled by one hoeing with *kasola* at 3 to 4 weeks after sowing. It should be repeated after 15-20 days if the weeds persist Weeds can also be controlled by spraying the chemical Triflurdin (Traflan) at 0.75 to 1.50 kg/ha in 250 litres of water before sowing and soil be harrowed immediately to mix the weedicide well with the soil.

6 5 1 5 Harvesting and Fodder Yield

The harvesting of crop for fodder may be started after 60 days of sowing and continued upto 75 days. Thereafter the crop will start loosing leaves and become woody and its protein content will be reduced In two cut management, the first cut can be taken after 50-55 days of sowing and the crop should be harvested at 15 cm above the ground level. The second cut can be taken at flowering stage i.e. 40 to 45 days after the first cut green fodder yield varies from 250 to 350 q/ha depending upon the variety, soil type and season.

6.5.2 Guar (Cyamposis tetragonoloba)

Guar is an important drought resistant legume of the arid and semi-arid regions of India grown during summer and kharif seasons Besides, it has multiple uses, viz., raised for fodder, green manuring, vegetable and seed purposes. India is the probable centre of origin of *C Tetragonoloba* It is also grown in Pakistan, Indonesia, Italy, America and Africa. In India it is grown in Rajasthan, Gujarat, Haryana, Punjab, Western Uttar Pradesh and in parts of Maharastra, Madhya Pradesh and Andhra Pradesh. Most popular and recommended varieties of this crop are *FS 277, HFG 119,* and *Guara 80.*

6 5.2.1 Soil and Its Preparation

Guar is grown on a wide range of soil types like light to heavy soils with good drainage as it cannot withstand waterlogging and excessive moisture. The crop prefers soil rich in phosphorus, potassium and calcium Minimum land preparation is required for *guar* crop. Two criss-cross ploughing with a *desi* plough or with harrow is enough for the desired tilth.

6.5.2.2 Sowing Time, Seed Rate and Method of Sowing

The crop can be sown as summer fodder from April to May where irrigation facilities are available. Being rainfed crop, it is mostly grown on the onset of monsoon from mid June to end of July. Generally, this crop is not taken as a pure crop for fodder But it is mixed with *bajra* or sorghum and harvested along with these crops In general, 35-40 kg seed/ha is sufficient for both branched and unbranched varieties. The pure crop should be sown in rows 30-40 cm apart by using *pora* or *kera* method For mixed cropping with *bajra* or sorghum in 2.1 ratio (cereal legume), 10-12 kg seed of *guar* per hectare is sufficient For mixed cropping, sowing by broadcasting is also followed

6.5.2.3 Fertilizer

Being a legume, nitrogen is normally not applied to *guar*. However, to give better start for the crop, 15-20 kg N/ha may be applied in soils poor in nitrogen *Guar* responds well to application of phosphorus and 50 kg P_2O_4/ha is enough for better nodulation and higher fodder yield. The whole dose of N and P may be applied at the time of sowing. When *guar* is sown in association with *bajra* or sorghum the fertilizer should be used in proportion to the recommended dose of the fertilizer for both these crops

6.5.2.4 Irrigation and Weed Control

In all it requires 2-3 irrigations which may be applied at 20-25 days interval depending upon season and rainfall. When *guar* is intercropped with *bajra* or sorghum 3-4 irrigations are needed. First irrigation in case of mixed cropping may be given 20-25 days after sowing and subsequent irrigations at 12-15 days interval during summer. Monsoon season crop does not require any irrigation if rainfall is well distributed Excess rain water should not be allowed to stagnate in the field, as it causes damage to the crop.

During summer season weed problem is minimum However, in monsoon season weed infestation is quite high and hence one hand weeding or hoeing by *kasola* at 25-30 days of sowing is required. Chemical weed control is also quite effective. Apply Basaline at 2.0-2.25 litre/ha in 250 litres of water before sowing and incorporate it well in soil otherwise there will be photo-oxidation of this chemical.

6.5.2.5 Harvesting and Fodder Yield

For higher yield and better quality of fodder, the crop should be harvested at 50 per cent flowering stage. The best state of harvesting is from flowering to pod initiation i.e about 60-75 days after sowing. Harvesting should not be delayed as it will lead to loss of digestible nutrients and palatability of the fodder Fodder yield varies from 250-300 q/ha depending upon variety, soil fertility, stage of harvest and season.

6.5.3 Berseem (*Trifolium alexandrium* L.)

Berseem known as Egyptian clover was introduced in India in the beginning of the nineteenth century. It is now being grown in rabi season extensively in states of Haryana, Punjab, Delhi, Himachal Pradesh, Uttar Pradesh and in some areas of Rajasthan and Madhya Pradesh It gives very high green fodder yield with frequent cuttings from late November to early June. It provides palatable, succulent and protein rich green fodder and hence it is called as king of forage It can be used for making hay during March-April. *Mescavi, Wardan, BL-1, BL-10, BL-22, JB-2* and *UPB-103* are the recommended varieties of *berseem.*

6.5 3 1 Soil and Its Preparation

Berseem can be grown on all kinds of soils except very sandy. But it grows vigorously on well-drained heavy loam soils rich in lime and phosphorus. It can also be grown on alkaline soils. Field should be well harrowed twice followed by planking Proper compartmentalization and bunding of whole field should be done to ensure proper distribution of irrigation water

6.5.3 2 Sowing Time, Seed Rate, Seed Inoculation and Method of Sowing

Sowing of *berseem* starts from middle of September and may continue up to end of October in the North and first week of December in Eastern India. Late sowing results in loss of one cutting The mixture of seed of Chinese cabbage with *berseem* seed ensures higher fodder production from *berseem* in the first cut.

Good quality 20-25 kg seed per hectare is sufficient. If the crop is to be sown in a new field where *berseem* has never been grown in the near past, there will be deficiency of *Rhizobium* bacteria in such fields. These bacteria are important for initial establishment and growth of the crop Hence seed should be treated with *Rhizobium* culture Prepare 10 per cent solution of *gur* in water, boil it for some time and cool. Mix the *Rhizobium* culture in this *gur* solution. Sprinkle the solution on seed and mix thoroughly so that every seed gets coated with *Rhizobium* Dry the seed in the shade and thereafter the seed is ready for sowing. A heavy irrigation is applied after proper bunding in the field and seeds are uniformly broadcaste in standing water Apply BHC dust all around the field so that black ants do not take away the germinating seeds.

6 5.3.3 Fertilizers

Application of 80 kg P_2O_4 and 25 kg N/ha in the field before sowing is normally done If farmyard manure is available apply 25 tonnes/ha and mix properly in soil 15 days before sowing and thereafter only 50 kg P_2O_4/ha should be applied as nitrogen will not be needed.

6.5.3 4 Irrigation and Weed Control

In early sown crop, first two irrigations should be light and applied at 5-7 days interval for good germination and proper establishment of crop. Successive irrigations should be applied at an interval of 12-15 days in October-November and February-March, 15-20 days in peak winter months and at 10-12 days interval in April-May.

6 5 3.5 Harvesting and Fodder Yield

First cutting should be taken at 50-60 days after sowing depending upon crop growth. Successive cutting should be taken at 40 days interval in winter and 35 days interval in February-March and in 25-30 days interval after March. In all the cuts, a good crop of *berseem* gives about 800-900 quintals green fodder/ha

6.5.4 Lucerne/Rizka (Medicago sativa)

Lucerne is a legumrnous crop capable of giving good fodder yield under irrigated conditions In India, it was introduced in 1900 and has now spread in several states. It is grown as a perennial crop in the drier regions and as annual crop in hot humid regions. The perennial crop of lucerne may provide fodder for 4-5 years, if this crop is kept free from weeds during rainy season. Being a legume, it fixes about 150 kg of nitrogen per hectare per year and provides nutritious fodder during the lean periods. It has persistency and tolerance to heat and droughts. Lucerne varieties like *T-9, LLC-3, Chetak, Anand-2* and *SS-627* are most popular in our country. *Anand-2* is an annual variety of Lucerne.

6.5 4 1 Soil and Its Preparation

Well drained loam soils rich in Ca^{++} and K^{+} are the best although lucerne can be grown even on sandy loam to clay soils A very good tilth is important for lucerne and hence the field should be cultivated 3-4 times and should be properly levelled to ensure uniform irrigation and proper drainage

6 5.4.2 Sowing Time, Seed Rate and Method of Sowing and Inoculation

In North India, sowing can be done from end of October to mid November. It may be sown up to December in Eastern region due to mild winter. In Southern region sowings are done in the winter months from October to December. About 9-10 kg seed per hectare is sufficient depending upon the soil type and seed size Sowing is done in rows, 30 cm apart by drilling the seed in the soil. Lucerne responds well to inoculation. If lucerne is grown for the first time in a field, its seed should be inoculated with specific *Rhizobium* culture before sowing as per method described for *berseem* to enhance nitrogen fixation and to obtain high fodder yield.

6.5 4 3 Fertilizers

As lucerne continues in the same field for about 4-5 years, apply 25 tonnes of farm-yard manure/ha before 15 days of sowing and mix well in the soil, 100 kg P_2O_5 per hectare should also be drilled before sowing 25 kg N/ha may be applied if the soil is poor in nitrogen or lucerne crop is taken after an exhaustive crop. During subsequent years, 125 kg P_2O_5/ha may be applied in the month of November using *desi* plough.

6.5.4.4 Irrigation and Weed Control

First irrigation should be applied about a month after sowing The optimum interval for subsequent irrigations is 10-15 days in summer, 15-20 days in spring and 20-25 days in winter During rainy season water should not be allowed to stagnate. In the first year weeds should be kept under control in the early stages When the weeds infestation is high in the monsoon season, frequent cuttings should be taken for better growth of lucerne. *Cuscuta,* a parasitic weed is most commonly found in lucerne which propagates vegetatively and through seeds. Affected lucerne plants along with this weed should be removed and buried in the soil.

6.5.4 5 Harvesting

The newly sown crop takes about 3-4 months to be ready for the first cutting. Subsequent cuttings may be taken at an interval of 30 to 40 days. In all 7-8 cuttings can be taken and about 750-800 q/ha fodder per year is generally obtained from lucerne crop.

6.6 Grasses

Grasses are, in general, perennial and grown under varying soil types and climatic conditions Napier grasses cultivated and other grasses can be grown both in cultivated and uncultivated lands

6.6.1 Napier Bajra Hybrid

This is a perennial cultivated grass which is an interspecific hybrid between Napier grass *(Pennisetum purpureum)* and *bajra (Pennisteum glaucum).* Napier *bajra* hybrid is quick growing and heavy yielder with better nutritive quality of fodder It can be fed to the animals as green fodder and in the form of silage. It contains oxalic acid which is harmful to the animals The crop is hardy, resistant to diseases and insectpests It is best adapted to the areas with hot and humid climate Most promising hybrids of this grass are : *NB-21, Pusa Giant, IGFRI-3 IGFRI-6,7 and 10, NB-83 NB-231* and *NB-233.*

6 6 1.1 Soil and Its Preparation

This grass can be grown on a wide variety of soils but light loam soil is preferred over others It survives waterlogged conditions to a considerable extent As the crop remains on the same field for about three years, it requires good preparation of field The field should be opened with a disc plough followed by 2-3 ploughing in criss-cross fashion by disc harrow or cultivator followed by planking

6.6.1 2 Planting Time, Propagation Material and Method of Planting

In Northern India it can be planted from early February to mid March and also in July and August. In central, southern and eastern regions where the mean temperature generally remains above 15°C, planting can be done throughout the year except in the cold months of December and January and the hot summer months of May and June

It should be propagated by root-slips or stem cuttings having 2-3 buds. After taking cutting for fodder, uproot the old clumps of this grass and separate the tillers along with their roots Each root-slip may consist of one or two tillers along with roots which should be inserted into the soil in such a way that half part of the root slip is allowed to remain in air while the rest of the portion is buried in the soil. This is the best method of planting. Irrigation may be applied immediately after planting the root slips

About 22,500 root-slips per hectare are required These should be planted with 75 cm distance from row to row and 60 cm from plant to plant. This row spacing and planting rate is for the pure crop of napier *bajra* hybrid.

In inter-cropping row to row distance is increased to two metres to permit sufficient space for the associated crops to grow satisfactorily In this case 8,400 root-slips are needed. In summer and kharif season, cowpea may be grown in association while in winter *berseem* + Chinese cabbage should be grown. Lucerne can also be taken in between napier *bajra* hybrid in winter, however, its crop remains suppressed due to rains in monsoon season

6 6 1.3 Fertilizers

Farmyard manure at 40-50 tonnes/ha may be applied 2-3 weeks before planting the napier *bajra* hybrid. At planting, apply 50 kg N + 40 kg P_2O_5/ha. During the first year apply 30 kg N/ha while in subsequent years 50 kg N/Ha may be applied after each cutting of the crop. Phosphorus at the rate of 40 kg P_2O_5/ha should be applied once in a year invariably in the beginning of March or with the first monsoon shower for the sustained production of good quality fodder of lucerne.

6.6.1.4 Irrigation and Weed Control

Apply one irrigation just after planting and thereafter two more irrigations at 7 to 10 days interval will be needed for establishment of crop, during spring planting. After the establishment of the crop, irrigation at 10-15 days interval should be applied in summer and at every third week after the monsoon season is over

Inter-culture should be done twice or thrice till the crop is fully established and starts growing vigorously. In mix cropping with lucerne, the field should be kept free from weeds.

6.6.1 5 Harvesting and Fodder Yield

The first cutting is ready in about 2 months after planting and subsequent cuts should be taken when the height of plants is between 75 to 100 cm which is generally attained within 35 to 40 days of the previous harvest of the crop depending upon the season It gives 5-6 cuttings in a year in the North whereas in South 7-10 cuttings can easily be taken as the mean temperature in this region generally does not fall below 15°C. The crop should be cut at 10-15 cm height from the ground level for proper regeneration. It yields about 1,000-1,500 quintals green fodder per hectare under pure crop and 1,500-1,600 quintals/ha in mixed cropping per year.

6.6.2 Guinea Grass (Panicum maximum)

Guinea grass is one of the best grasses amongst the pasture grass species Being perennial once established it can yield economically upto 12 to 15 years This grass species competes fully with most of the weeds and it has the mechanisms to spread naturally There are many varieties of this grass like *Hamil, Makueni, PGG-9, PGG-13, PGG-14* and *PGG-19* which are most popular and widely grown in many states of the country.

6.6.2.1 Soil and Its Preparation

This is suited to a wide range of soils but it grows well in light textured clay loam soil with well drainage facility For a very good production the land should be ploughed three to four times to prepare good seed bed. In forest land it can be grown without cultivation.

6.6.2.2 Sowing Time, Seed Rate and Sowing Method

It is better to establish this grass in the month of March and April under irrigated conditions, whereas in rainfed areas this grass can be sown in the month of July. The seeds of this grass are very small, 2 to 3 kg seed/ha for raising nursery and 6 to 8 kg/ha for direct sowing in the field is needed For vegetative propagation 30,000 to 40,000 root-slips of this grass are sufficient for one hectare

The seed may be sown directly in line spaced 60 cm apart and plant to plant distance of 30 cm should be maintained Seed should not be placed more than 0.4 to 1 cm deep The seed can also be sown by broadcast in uncultivated area using slightly higher seed rate. This grass is established more easily by root-slips and the planting distance will be same as in case of sowing by seed.

6.6.2.3 Fertilizers

Well rotten 35 to 40 tonnes farmyard manure may be applied in one hectare and mixed with the soil thoroughly. After each cutting of grass 70 to 75 kg urea/ha should be applied for faster growth of the crop If farmyard manure is not available then 100 kg urea and 100 kg of Di-Ammonium Phosphate (DAP) per hectare may be applied at the time planting.

6.6.2.4 Irrigation and Weed Control

Guinea grass needs heavy irrigation at every 15 to 20 days interval. After each cutting irrigation should invariably be applied During rainy season it needs no irrigation while in the summer season frequent irrigation is necessary At initial stages of establishment of grass field should be kept free of weeds by regular inter-culture operation.

6.6.2.5 Harvesting and Fodder Yield

Proper and timely harvesting of this grass is very important The grass should always be harvested at the ground level. Harvesting should not be done just after irrigation First harvest can be taken at 70 to 75 days after planting, whereas subsequent cuttings should be done with sharp implement at 35 to 40 days interval In all 6 to 8 cuttings can be taken in a year Normally this grass produces 1,000 to 1,500 quintals green fodder per hectare per year. Its fodder contains about 6.5 to 7.5 per cent crude protein and is good for silage making.

6.6.3 Signal Grass (Brachiaria decumbens)

Signal grass is a very good grass for marshy areas. It is a spreading type of grass. Its stem is soft which grows upto 60 to 70 cm height It has large number of leaves with dark green colour and fine hairs The seeds are almost round and covered with husk. It is a moisture loving grass but does not prefer standing water. It regenerates very fast and competes with other weeds quite effectively. This grass spreads both through self seeding and *rhizomes*. So far there is no recommended variety of this grass

6.6.3.1 Soil and Its Preparation

This grass is adapted to a wide range of soils but for its good growth clay soil is the best In sandy soil it does not grow well It can be grown in acidic soils also. It can be grown without cultivation of land but for good production of fodder it is better to prepare land by ploughing 3-4 times followed by planking

6.6.3.2 Sowing Time, Seed Rate and Sowing Method

This grass should be planted in the beginning of the rainy season. But under assured irrigated conditions it can be planted any time in spring season Six to eight kg seed/ha is needed for broadcasting on uncultivated lands. For raising seedlings in seed bed three to five kg seed/ha and in line sowing four to five kg seed/ha will be required. For planting by root cutting about 30,000 to 40,000 root-slips are sufficient for one hectare Use of root-slips is better than seed for establishment of the grass Root-slips/seedlings may be planted at 50 × 30 cm distance Seed may be sown in lines 50 cm apart at a depth of not more than 0 5 to 1 cm Before sowing the seed may be treated with concentrated sulphuric acid for better germination

6.6.3 3 Fertilizers

Signal grass needs 40-45 tonnes of FYM per hectare which may be applied twice in a year In case of non-availability of FYM, 100 to 150 kg urea and 50 to 60 kg DAP/ha may be applied at the time of sowing For better crop growth 50 kg urea/ha may also be applied after each cutting

6 6 3 4 Irrigation and Weed Control

If the sowing of its seed has been done in field with proper moisture, the first light irrigation should be applied within a week after sowing. In case of planting by root-slips the field should be heavily irrigated immediately after completion of plantation and later on at 15-20 days interval depending upon weather conditions and frequency of cutting the grass. Irrigation, immediately after harvesting the grass, is very necessary for faster regeneration and better growth The weeds should be removed by hoeing at the early stage of the crop so that weeds do not suppress the seedlings

6.6 3 5 Harvesting and Fodder Yield

First harvest should be taken 60 to 70 days after planting Subsequent cutting can be done at every 45 to 50 days interval Cutting should always be done at the ground level In winter and summer seasons the interval for harvesting will be slightly longer. It produces 650 to 700 quintals of green fodder/ha/year. Fodder of this grass is highly palatable and contains 6 to 7 per cent protein This grass is suitable for hay making

6.6.4 Rhodes Grass (Chloris gayana)

This grass has a thin stem which grows erect but sometimes it spreads on the ground. The leaves are thin 30 to 40 cm long and 0.5 to 1 cm broad The inflorescence consists of two to five slender spikes of 10-12 cm length based on which this grass can easily be identified. This grass is propagated by seeds and root-slips

Rhodes grass is tolerant to drought and alkalinity and hence survives for a long time under adverse conditions It remains dormant in winter and regenerates thereafter This is a very good grass for horses. Its main varieties are *Collide, Katambora* and *Pioneer*

6.6.4.1 Soil and Its Preparation

For its good growth sandy loam soil with drainage facility is most suitable. It can also be grown on alkaline soils. This grass prefers well prepared soil with fine tilth and hence field should be ploughed 2-3 times with harrow followed by planking.

6 6 4 2 Sowing Time, Seed Rate and Sowing Method

The best time for sowing of this grass is monsoon season preferably from July to mid August The seeds are very light and only two to three kg of seed/ha is enough. About 25,000 to 30,000 root-slips are needed for planting in one hectare It is better to grow this grass in lines spaced 50 to 60 cm apart and plant to plant distance of 30 cm should be maintained The germination of the seed is generally good and hence its seed may be sown directly in the field at a depth of 2-3 cm or else seedling may be raised in the nursery and then the same should be transplanted at above mentioned spacing

6.6.4.3 *Fertilizers*

For better growth of this grass 20-30 tonnes of farmyard manure per hectare may be applied at the time of land preparation. If farmyard manure is not available then 150 to 200 kg N and 30 to 40 kg P_2O_5 per hectare per year may be applied. Half of this nitrogen and full P_2O_5 may be applied at the time of sowing and remaining nitrogen may be applied after each cutting equally

6.6.4.4 *Irrigation and Weed Control*

Irrigation is very important for good growth of this grass. In high rainfall areas this grass needs irrigation only in the summer and winter seasons at 15-20 days interval depending upon rains, but in other areas it needs water at every 10 days interval At early stages of crop the field should be kept weed free following inter-culture operations otherwise seedlings may well be suppressed by weeds resulting in poor crop.

6.6.4.5 *Harvesting and Fodder Yield*

This grass should always be cut at the ground level and its roots should not be damaged. First harvest can be taken 70 to 80 days after planting and later cutting should be taken after every 30 to 35 days interval. It produces 600 to 650 quintals of green fodder/ha/year. This grass is excellent for making hay. Among all the grasses, Rhodes grass contains maximum protein (8-10 per cent) This grass is highly palatable

6.6.5 Buffel Grass (Cenchurus cailiaris)

This grass is perennial, fast growing thin stemmed and hardy. The leaves are soft, long (20-25 cm), broad and droopy. Its flowers look like a fox tail and seeds are very small and covered with a hairy flap. Being drought hardy buffel grass is widely adapted in arid and semi-arid areas and grows well under low rainfall for many years. *Varieties Biolela, Gayandh, IGFRI-3108* and *Marwar Anjan* are most popular in the country.

6.6 5.1 *Soil and Its Preparation*

This grass can be grown in a wide range of soils but sandy to sandy loam soils with good drainage facility are best for its good growth. It needs well prepared seed bed. But it can also be grown on uncultivated lands. For its good growth and better fodder production the land must be ploughed two to three times before sowing with harrow or cultivator followed by planking.

6.6.5 2 *Sowing Time, Seed Rate and Sowing Method*

Best period for sowing of this grass is rainy season from July to mid August The seed of this grass is very light and two to three kg seed is sufficient for sowing in one hectare. For broadcasting four to five kg seed per hectare will be needed For efficient interculture and good production it is better to sow the seed in lines at 60 cm distances The seedling can also be raised in the nursery and then transplanted in the main plot at a distance of 60 × 30 cm. Its root-slips can also be planted at above distance Seed should be mixed with wet soil for its uniform sowing and good germination.

6.6 5 3 *Manure and Fertilizer*

It gives very good response to application of farmyard manure (20 to 25 tonnes/ha) which must be mixed thoroughly with the soil at the time of ploughing the field. In case of non-availability of farmyard manure, 40-50 kg P_2O_5 and 20 kg/N per hectare may be applied at the time of sowing. After first cut and subsequent cuttings 20-30 kg N/ha may be applied as top-dressing after irrigation.

6.6.5.4 Irrigation and Weed Control

If there is no rain, light irrigation should be given at 7-10 days after sowing. In case of planting by seedlings or root cuttings irrigation after completing of plantation is very necessary for establishment and faster sprouting of the cuttings Subsequently, the field should be irrigated after 10-15 days interval depending upon rains. Immediately after germination of seeds and sprouting of cuttings there may be heavy infestation of weeds which should be removed by weeding and hoeing, otherwise there will be great setback to the crop.

6.6.5.5 Harvesting and Fodder Yield

Harvesting should always be done from the ground level. First cutting can be taken at 60 to 70 days after planting, thereafter it can be harvested at 35-40 days interval in the rainy season Under rainfed conditions it gives three to four cuts in a year and produces 400 to 450 quintals of green fodder but its fodder yield under irrigated conditions is 500-600 quintals/ha. Buffel grass is very palatable. Its fodder contain 6 to 7 per cent crude protein. It is very good grass for sheep and goat. Good hay can be prepared from this grass

6.7 Pasture Legumes

In India, there are vast areas under forest where it is possible to grow pasture legumes without disturbing the forest trees The pasture legumes add nitrogen to the soil which leads to faster growth and better yiel of the forest trees. Moreover, the pastur legumes are very hardy due to their ver deep root system and hence these do nc require much care for irrigation an fertilizer. Once established, pasture legume continue for many years.

Pasture legumes are sown by see directly in the field Normally, the pastu legumes need one year for fu establishment, however, first cutting/grazin may be done at flowering in 90-100 da after sowing and subsequently pastu legumes can be cut or grazed at 60-65 da interval. In winter season pasture legum will give less yield due to low temperatu and their slow growth. There are differe types of pasture legumes out of whic following few species are most important

6.7.1 Centro (Centrosema pubescens)

Centro is a climbing perennial legun which is very leafy and forms comple dense cover on soil within a short perio The leaves are dark green and its stem slightly round. This is a very good legun for medium to high rainfall areas requiri minimum rainfall of 750 mm and gro well where annual rainfall is more th 1,500 mm

6 7.1.1 Soils and Its Preparation

It can grow on wide range of soils fr sandy loam to clay soil, but it grows w in heavy clay loam to clay soils. It al grows well on hilly and alluvial soils. prefers fertile soils but it also grows on p soils Two to three ploughings with trac or *desi* plough are needed. In forest land is grown without any cultivation.

6.7.1.2 Sowing Time, Seed Rate and Method of Sowing

Sowing should be done in June and July with the onset of rains. For cultivated lands three to four kg of seed/ha is required. The seeds should be sown in rows at 50 cm distance between rows at a depth of two to three cm. The seed should be slightly covered with soil In case of uncultivated lands five to six kg seed/ha is needed. For good germination the seed should be treated with boiling water for one to two minutes.

6.7 1.3 Fertilizers

Centro requires less fertilizer in fertile soils. But in low fertile soils it needs more phosphorus and potassium. Calcium application increases its yield. For good growth it needs 100 to 110 kg P_2O_5 and 30 to 40 kg K_2O/ha/year. All the fertilizer should be applied once in a year at the time of last ploughing of the field

6.7 1.4 Irrigation and Weed Control

During rainy season irrigation is not required. But in case of failure of rains, the crop may be irrigated at 15-20 days interval. After harvest of the crop, field should be irrigated for proper regeneration and better growth of the crop One or two weedings are needed to control weeds at early stages of the crop.

6.7.1.5 Harvesting and Fodder Yield

Centro cannot stand heavy grazing. It can be used for cut and carry system. It can be fed as green fodder at any stage of its growing period. It produces 800 to 850 quintals of green fodder/ha/year, which contains 12 to 16 per cent protein

6.7.2 Glycine (Neonotonia wightii)

This legume grows under both low (500-600 mm) and high (1,000 to 1,800 mm) rainfall areas. It is a shade loving perennial legume for irrigated pasture It climbs up to the top of big trees within 3 to 4 months time The stem is slender and elongated The leaves are dark green. Its flowers are small and cream coloured.

6.7 2.1 Soil and Its Preparation

This legume can be grown in a wide range of soils like loam to clay soil and also in hill slopes. But it does not grow well on sandy loam soil Land should be prepared thoroughly by ploughing two to three times with harrow or cultivator followed by planking It can be grown well without cultivation of land also

6 7.2 2 Sowing Time, Seed Rate and Method of Sowing

The month of July during rainy season is the best period for its sowing. For obtaining good results, four to five kg seed/ha of this legume is needed. The seed may be sown by *pora* or *kera* in lines having line to line distance of 50 to 60 cm. Seed should be sown at a depth of two to three cm in the soil. In an unprepared seed bed and sowing by broadcast, the seed rate will be six to eight kg/ha. The seed may be dibbled by hand under the forest trees. For good germination, the seed should be treated in boiling water for two to three minutes.

6.7.2.3 Fertilizers

Glycine does not require any application of nitrogenous fertilizer. Rather it adds 150-200 kg of nitrogen/ha/year except in waterlogged areas For good growth of fodder and seed production, 100-120 kg of

P_2O_5 and 30-40 kg K_2O/ha year are needed. These fertilizers should be applied once a year

6.7.2.4 Irrigation and Weed Control

In case of long gap in rainfall, the field should be irrigated at an interval of 15-20 days But there is no need of irrigation when rain is well distributed Depending upon weed infestation one to two good hoeings are necessary to make the crop weed free

6.7.2.5 Harvesting and Fodder Yield

Glycine is used for cut and carry system It can not tolerate heavy grazing Cattle like this legume very much Cattle can eat even the hard stem of this legume. In rainy season, animals can be allowed for grazing after every 40-50 days interval. This legume produces 550-600 quintals of fresh fodder/ha/year in four to six cuts.

6.7.3 Siratro (Macroptilium atropurpureum)

Siratro is deep rooted perennial legume Its stem produces roots along the length in the moist clay soil The leaves are dark green and slightly hairy on the upper side The flowers are deep purple with reddish tinge near the base of the petals The seeds are light brown to black in colour It is a drought resistant forage legume which can be grown under rainfall below 500 mm. It is a very good legume for grass-legume mixture.

6.7.3.1 Soil and Its Preparation

Siratro can be grown on a wide range of soils with good drainage facility. For good growth, it needs sandy loam soil but it can also be grown well in light clay soil This legume is one of the best legumes for moderately saline conditions. Siratro can also be grown on degraded soils and waste-lands For good growth the land should be ploughed twice criss-cross wise to prepare it well before sowing It can also be grown on uncultivated lands like forest areas

6.7.3.2 Sowing Time, Seed Rate and Sowing Method

Sowing should generally be done in the month of July during rainy season. Four to five kg seed/ha is required. The seed may be drilled in line having a distance of 50 cm between lines and seed should be sown at a depth of two to three cm. For unprepared land seed rate will be six to eight kg/ha On the forest land, the seed can be sown by broadcast as well as in lines The seed should be treated in boiling water for one to two minutes for its good germination

6.7.3.3 Fertilizers

Siratro needs 100-200 kg phosphorus and 30-40 kg K_2O per hectare for its good growth for fooder and seed production in a year. An application of two tonnes of lime/ha in the soil increases the yield of both green fodder and seed Siratro does not need nitrogenous fertilizer as it adds 100 to 150 kg/ha nitrogen per year in the soil.

6.7.3.4 Irrigation and Weed Control

Being drought hardy Siratro does not need irrigation even in long spell of drought. But in case if drought is severe irrigation should be applied at 15-20 days interval in early stage of the crop. One to two weedings should be done to remove the weeds from the field in the early stages of the crop.

6.7.3.5 Harvesting and Fodder Yield

Siratro cannot withstand heavy grazing and therefore, it should always be grazed lightly. Siratro can also be used for cut and carry system and it produces 650 to 700 quintals of green fodder/ha/year.

*6.7.4 **Axillaris (Macrotyloma axillare)***

Axillaris is a trailing and twining perennial legume with hairy stem Its stem and leaves are bright green. The flowers are small and greenish yellow. Although, it can tolerate high rainfall more than 2.250 mm, it is also very good drought tolerant legume.

6.7.4.1 Soil and Its Preparation

Axillaris can be grown well in sandy loam to loam soils with good drainage system. It cannot be grown on waste and degraded lands. It grows well in properly prepared seed bed, therefore, land should be prepared by ploughing three to four times with harrow or cultivator. It does not establish well in uncultivated land in forests due to its non-tolerance to shade

6.7.4.2 Sowing Time, Seed Rate and Sowing Method

The whole month of July is most suitable for plantation of this legume. Five kg seed per hectare is needed for maintaining proper stand of the crop. There are hard seeds in this legume hence, for good germination the seed must be treated in boiling water for two to three minutes After sowing of the seed by *kera* or *pora* in lines at 40-45 cm distance the seeds should be given light cover of soil It can also be sown by broadcast.

6.7.4.3 Fertilizers

Axillaris needs 70-80 kg P_2O_5 and 20-30 kg k_2O per hectare/per year for higher production of fodder and seed. These fertilizers should be applied to the soil in the first week of August. Being a legume, it does not require nitrogenous fertilizer.

6.7.4.4 Irrigation and Weed Control

During the rainy season there is no need of irrigation provided rainfall is well distributed, otherwise, crop should be irrigated at 15-20 days interval for proper growth One or two hoeings are enough to control the weeds at 30-35 days stage of the crop

6.7.4 5 Harvesting and Fodder Yield

Axillaris cannot tolerate heavy grazing, hence always light grazing may be followed. Winter grazing is harmful to the crop In thin planting, seed should be allowed to shatter for a year. It should be cut frequently after 100 days of its sowing for its good growth It produces 500 to 600 quintals of green fodder/ha/year. Its fodder is highly palatable

6.7.5 Fine Stem Stylo (Stylosanthes guianensis)

This is a strong deep rooted perennial legume. Due to its delicate stem it cannot stand straight The leaves are narrow and 39 to 59 cm long. The flowers are yellow and small. The pods are hairy and small having yellowish brown seeds. Although, this species is deep rooted it needs more moisture and does not tolerate drought. It needs a high rainfall of 1,500 to 2,000 mm.

6.7.5.1 Soil and Its Preparation

Stylo grows well in light textured and well drained soils. It cannot be grown well in heavy soils. Sandy loam is the best for its good growth. It does not grow properly on saline soils. The land should be ploughed two to three times for better growth of the crop It can be grown on unclutivated lands like forest areas.

6 7.5.2 *Sowing Time, Seed Rate and Method of Sowing*

Stylo is a very good pasture legume for natural spread. Once established, it can spread in large areas within a few years. Its sowing in the month of July is the best for good germination and growth of the crop. About two to three kg seed per hectare is enough. For sowing in lines, the line to line distance should be 50 to 60 cm. It can also be sown by broadcasting. Stylo seeds are very small, so its seeds require one to two cm soil cover for good germiantion. For proper and uniform sowing the seed should be mixed with sand or soil before sowing. In case of uncultivated land four to five kg/ha seed is needed. The seed should be treated with boiling water for two to three minutes for its good germination.

6.7 5.3 *Fertilizers*

This legume does not require application of nitrogenous fertilizer rather it adds 100 to 150 kg nitrogen per hectare per year. As Stylo needs more phosphorus for its good growth 100 to 150 kg P_2O_5/ha/year is sufficient. Every year, phosphorus needs to be applied at the beginning of the rains. It also needs 30 to 40 kg K_2O/ha/year for better production.

6.7.5.4 *Irrigation and Weed Control*

Irrigation and weed control at early stages of the crop are very important. Under proper rainfall in monsoon season there is no necessity of irrigation. In case of failure of rains the crop needs to be irrigated at 15-20 days interval Care should be taken to maintain weed free crop by doing one or two hand weedings.

6 7.5 5 *Harvesting and Green Fodder Yield*

The crop should be harvested at the flowering stage. Under normal growth, it can produce 550 to 600 quintals/ha of green fodder. In rainy season fodder can be cut or grazed at every 40 to 45 days interval. In case of delay in harvesting the fodder yield will be less due to damage to the crop. Its seed have to be collected by sweeping from the ground as most of it shatters at maturity.

6.7.6 *Caribbean Stylo (Stylosanthes hamata)*

Caribbean Stylo is an annual and is also short lived perennial legume. It is semi-erect in growth and can grow 50 to 75 cm in height The leaves are narrow and smaller. Its flowers are yellow and small with eight to ten flowers in each inflorescence. The seeds are dark brown, small and shatter at maturity. This Stylo is very drought tolerant. It can survive in a long dry season but grows well in 400 to 500 mm rainfall. It spreads naturally by seed drop and covers large areas in a short period.

6.7.6.1 *Soil and Its Preparation*

This legume is adapted to a wide range of soils. For good growth, it needs clay loam soil. But it can also be grown well on hill slopes and stony lands. It is a good legume for control of soil erosion. It can be grown on the bunds of the land. It cannot tolerate water-logged conditions and hence good drainage facility in land is required for its better growth Caribbean stylo can be grown well in uncultivated land Cultivated lands may be prepared by ploughing three to four times

6.7.6.2 Sowing Time, Seed Rate and Method of Sowing

Crop should be sown with the onset of rains. Normally it requires three to four kg seed/ha In case of uncultivated lands the seed rate will be little higher i.e five to six kg/ha. The seed must be treated in boiling water for two to three minutes for its good germination For proper management and growth of the crop, sowing should be done in lines at 50 cm distance In uncultivated land, the seed should be broadcasted. The seeds are very small and hence sowing should be done at two to three cm depth of the soil

6.7.6.3 Fertilizers

It does not require nitrogen fertilizer, rather it adds 100-150 kg N/ha per year in the soil. For good growth of the crop, it needs 50-60 kg P_2O_5 and 20 to 30 kg K_2O/ha/year which should be applied at the time of preparation of field

6.7.6.4 Irrigation and Weed Control

If there is no proper and well distributed rainfall after sowing of the crop, irrigation should be done at 15-20 days interval Weeds should be removed by one or two hand weedings in the field at early stages of crop so that stand and growth of the crop are good to obtain high yields

6.7.6.5 Harvesting and Fodder Yield

Havesting should be done at flowering stage. It also tolerates heavy grazing. The plants can grow even if the crop is grazed at ground level In case of cutting method it should be always harvested at ground level. It gives about 800 quintals/ha/year fodder yield in six to eight cuttings

6.7.7 ***Shrubby Stylo (Stylosanthes scabra)***

Shrubby stylo is a perennial legume and grows erect with a strong woody stem Its stem is hairy varying in colour viz., pale green to dark blue green, brown to reddish depending on the cultivation. The colour of the leaves is generally dark green The seeds are very small with pale to light brown colour. Among all the forage legumes, *S scabra* is the most drought tolerant species due to its deep roots and can be grown even in 400 mm rainfall. For its good growth, it requires 600 mm rainfall It does not tolerate waterlogging

6.7.7.1 Land and Its Preparation

Shrubby Stylo is a very good legume for wastelands where other legumes and grasses cannot grow For its good growth, it needs sandy to sandy loam soils It can be grown in infertile acidic soils and stony lands and hill-tops but cannot be grown in heavy clay soils. *S. scabra* can be established without any cultivation of land Two to three ploughings with harrow or cultivator are sufficient to prepare the land for sowing.

6.7.7.2 Sowing Time, Seed Rate and Sowing Method

Shrubby Stylo can be sown well by broadcasting the seed as well as in line at 50 cm distance In case of line sowing, the seed should not be sown more than two to three cm deep and there is no need to cover the seeds For proper sowing, the seed may be mixed with soil to increase the volume of seeds.

About four to five kg seed/ha is needed for uncultivated lands In well prepared soils, the quantity of seed may be reduced to two to three kg/ha. The seed must be treated in boiling water for three to five minutes for its good germination.

6.7.7 3 Fertilizers

Shrubby Stylo can be grown, well in soils with low fertility where other crops cannot be grown well Shrubby stylo requires good amount of phosphorus which increases both fodder and seed yield of this legume Every year, it needs 100 to 120 kg P_2O_5/ha Shrubby stylo also responds well to the application of 20 to 30 kg k_2 O/ha/year.

6 7 7 4 Irrigation and Weed Control

Since this legume is raised during the rainy season there is no need of irrigation provided rainfall is good and properly distributed In case of shortage of rainfall, crop should be irrigated at an interval of 15-20 days. In this legume weeding is not required as shrubby stylo is a very good legume for weed control. Once established it can control almost all weeds If weeds infestation is most serious at early stages of the crop, one to two hand weedings are enough to control the weeds

6.7.7 5 Harvesting and Green Fodder Yield

S. scabra can withstand heavy grazing and plants will not die even if the stem becomes woody It gives more yield by cutting and hence crop should be harvested at flowering stage It can produce 600 to 650 quintals of green fodder per year The seeds remain with the stem at maturity Therefore, the plant should be cut and the seed can be collected by threshing

QUESTIONS

1 Define the terms 'Forage' and 'Fodder' Give the broad classification of forage crops.
2 Give the importance and advantages of forage crops
3 Write the salient characteristics, harvesting stage and fodder yield of cereal fodder crops.
4. Specify about the following for crops like *Jowar*, Maize, Teosinte and Oat
    (i) Sowing time
    (ii) Seed rate
    (iii) Method of sowing
    (iv) Fertilizer requirement.
    (v) Irrigation and weed control.
5 Explain the production and management of single cut and multicut varieties of *Jowar* and Oat
6. Name the fodder crops used for mixed cropping with cereal fodders and write about the cultivation practices of any one of them.
7 Give in short about the cultivation practices of *Berseem* crop
8. Name the cultivated legumes grown as annual and perennial crops for fodder Write their production technology
9 Describe the cultivation practices of Napier *bajra* hybrid
10 Name the varieties of following grasses
    (i) Guinea grass

(ii) Rhodes grass

(iii) Buffel grass.

Write about the production practices of any of the above grasses.

11. Which grass is suitable for growing in marshy areas and how is it cultivated? Explain in detail
12. What are the advantages of pasture legumes? Name the various types of these legumes and describe their differentiating characteristics.
13 Describe the cultivation practices of one of the stylos in detail.
14. Write the rainfall, seed rate, sowing time and fertilizer requirements of following pasture legumes What are their fodder yields per hectare?

(i) Centro

(ii) Siratro.

(iii) Axillare.

CHAPTER 7

Crop Rotation and Cropping Scheme

IN initial stages of agriculture it was a very common practice to grow the same crop in the same field continuously. Eventually, the yield of crops used to decline due to depletion of soil fertility. Therefore, the idea of diversification in cropping came and growing of crops in rotation was suggested in order to obtain higher yields and to maintain the fertility of soils.

7.1 Crop Rotation

7.1.1 Definition of Crop Rotation

1. Crop rotation is the growing of various crops on a piece of land in a pre-planned succession.
2. Crop rotation is a cropping system in which crops are raised on a piece of land in recurrent succession so as to maintain fertility of land and to obtain maximum yield from crops.
3. Crop rotation is an order in which chosen crops are cultivated on a piece of land over a fixed period.

7.1.2 Objectives and Principles of Crop Rotation

7.1.2.1 Objectives

The main objectives of raising crops in scientific rotation are :

(i) Maintenance of fertility of the land It does not mean crop rotations would replace manuring rather it is an aid in achieving this objective.

(ii) Production of crops in an economic manner.

7.1.2.2 Principles

While framing a good crop rotation to achieve the above objectives, the following main principles should be kept in view:

(i) Non-leguminous crops should be followed by leguminous crops requiring less manuring.

(ii) Crops requiring heavy manuring should follow crops requiring less manuring.

(iii) Deep rooted crops should follow shallow rooted crops.

(iv) Leaf shedding crops like jute, cotton and pulses should follow non-leaf shedding crops like wheat or rice.

(v) Field should be kept fallow or a green manuring crop should be followed by an exhaustive crop.

(vi) Crops requiring more tillage and irrigation operations should follow a crop requiring less tillage and irrigation.

(vii) The crops that are susceptible to soil borne pests and diseases should be followed by tolerant crops

(viii) Perennial or long duration crops should be followed by seasonal crops.

(ix) Fodder crops should be followed by grain or vegetable crops

(x) Erosion permitting and toxicants producing crops should not be included in the crop rotation

(xi) Crop rotation should be such that it fulfils the domestic needs of the farmer who could afford to grow the same.

(xii) Rotation of crops should provide employment to labourers and use of bullock power all the year round.

(xiii) Crops should be selected according to the soil and climatic conditions of a particular locality

(xiv) Multicut forage crops like oat, *berseem,* sorghum and pasture crops should succeed seed crops.

(xv) Crops with problematic weeds should be followed by cleaning/multicut crops.

7.1.3 Pre-Requisites of Crop Rotation

There are some pre-requisites in order to follow suitable crop rotations which are given below :

(i) The farm should have either equal or a multiple number of blocks or fields of equal size as the number of years for which rotation is adopted.

(ii) Each block or field area should be properly levelled and each field or the blocks should have equal physical facilities, such as soil fertility and condition, irrigation and drainage, and approach road, etc.

(iii) The area meant for each crop should be uniform in which field operations could be done conveniently.

(iv) Provision of elasticity within the cohesiveness of crop rotation should exist so that substitution of crops as per conditions and needs could be done.

7.1.4 Considerations or Factors Affecting Crop Rotation

There are number of considerations or factors playing an important role in choosing crop rotations The choice of a rotation for a particular farm depends upon following factors ,

(i) *Suitability of Crops* : The choice of crops which can be included in a crop rotation will depend upon their adaptation to the conditions of a particular area/region

(ii) *Climate* . If farm is situated in high rainfall and temperature areas then crops with high temperature and water requirement like paddy or vice-versa should be taken

(iii) *Soil Type* : If soil of farm is heavy then crops like wheat, sugarcane and cotton are grown, whereas on light soils groundnut, tobacco, green gram and root/tuber crops should be grown. Wet soil is better for rice, paragrass and *dhaincha* Dry soil is better for pulses, oil-seeds, sorghum and *bajra*

(iv) *Marketing Facility* · If farm is near to a city then sugarcane, vegetable and forage crops should be given preference as compared to grain crops or vice-versa.

(v) *Fitting in the Farming System* : The new crops included in crop rotation should fit well in the main farming systems like dairy farm, vegetable farm and grain farm i e. fodder crops for livestock on a seed farm or grain crops for human consumption on a dairy farm should be grown in smaller area as compared to main crops.

(vi) *Maintenance of Fertility of Soil* · A well-planned rotation will help to maintain/improve soil fertility through improvement in soil structure and nutrients availability, micro-environement, inclusion of smothering and cleaning crops, and adoption of cultivation at different times

(vii) *Control of Insectpests and Diseases*: Many of the insectpests and diseases are specific to one or the other crops. But when different crops are grown these are killed and further multiplication thereof is also checked

(viii) *Economic Condition* : Rotations, except in case of an alternate grain fallow system, provide diversification of crops which may assure more economic use of irrigation, water, labour and other facilities. Morevoer, there is less risk of complete failure in crop rotation due to weather, pests and low prices than with one crop and yield is also high.

7.1.5 Rotation and Cropping Intensity

(i) *Rotation Intensity (RI)*: Rotation intensity refers to the number of crops taken in a rotation in one year which is taken 100 per cent for one crop

$$\text{RI} = \frac{\text{No of crops in a rotation}}{\text{No of years of rotation}} \times 100$$

For example, if four crops are taken in one year then rotation intensity will be 400 per cent

(ii) *Cropping Intensity (CI)* . Cropping intensity is the ratio between total cropped area and actual net cultivated area expressed in percentage

$$\text{Cropping intensity (\%)} = \frac{\text{Total cropped area}}{\text{Net cropped area}} \times 100$$

Which in the crop rotation chari-Toria-Mung covering land area of one acre the cropping intensity will be 3/1 × 100 = 300 per cent.

However, it does not take into account the length of growing period of the various crops.

7.1.6 Classification of Crops for Rotation

Crops can be classified into following categories for their use in crop rotation.

(i) *General Crops or Exhaustive Crops* Most of the cereal crops are called exhaustive crops due to their higher uptake of nutrients like nitrogen, phosphorus and potash If these crops are grown continuously in the same field they encourage weeds, fungal diseases and pests resulting in reduction in the yield. These crops require more labour for various operations.

(ii) *Clean or Root and Tuber Crops* . These are mostly cash crops like potatoes, carrot, and radish Due to timely cultivation before and after plantation these crops control weeds. Therefore, these crops are called cleaning crops and need more labour

(iii) *Break Crops or Legume Crops* : These crops are mostly leguminous crops viz peas, *moong, moth,* soybean and *arhar* which provide a break from continuous cereal growing

(iv) *Restorative or Green Manure Crops* . These crops restore soil fertility by bringing nutrients from deep layers to the soil surface and by addition of organic matter These are leguminous crops ploughed up in the field for green manuring e.g. *dhaincha, sunhemp.*

7.1.7 Advantages and Disadvantages of Crop-Rotation

7.1.7.1 Advantages

(i) Good yield are obtained without any extra expenditure.

(ii) Plant nutrients are utilized in a better way from all zones of soils due to varying nutrient requirement of crops.

(iii) Weeds, insectpests and diseases are controlled or their infestation is reduced

(iv) Irrigation water is utilized judiciously.

(v) Introduction of newer crops to non-traditional season and area is possible.

(vi) If main crops cannot be sown, cash crops are taken.

(vii) Soil fertility is maintained and improved by use of legume crops.

(viii) No accumulation of harmful secretions as is the case of regularly growing cotton

(ix) Harvesting of some crops like potato reduces preparatory tillage operations for the next crop.

(x) Risk of crop failure is reduced.

(xi) There is control of soil erosion

(xii) Labour, power and capital are utilized in a better manner throughout the year

7.1.7.2 Disadvantages

(i) Growing of different crops in rotation needs preservation and/or procurement of various seeds, specialized implements and equipment which may not be locally available.

(ii) Special care and maintenance of all crops may not be possible due to want of skilled labour

(iii) Repetition of same crop rotation for years may nullify the long-term benefits of such cropping.

(iv) Shifting to the crops based on priority and demands may be difficult

7.1.8 Some Main Crop Rotations

The crop rotations for irrigated and rainfed areas vary because the crops used for growing differ The duration of crop rotations vary from one to five years. Some important crop rotations are given as under .

(a) **Forage-grain crop rotations**	**Duration**
Forage Maize-Cowpea-Wheat	One year
Sorghum-Potato-*Bhindi*	One year
Forage Maize-Toria-Sugarcane	Two years
-Sorghum Mutlicut-Wheat- -Sugarcane	Two years
Cotton-Oat Multicut-Gram	Two years

	Bajra-Berseem-Sorghum	
	Multicut-Gram-*Bajra* (Fodder) -*Raya*	Three years
	Cowpea-Sugarcane-Ratoon-Sorghum-Cowpea-Wheat	Four years
	Maize-Cowpea-Sugarcane-fallow-Wheat-Paddy-Senji-Sorghum-Wheat	Five years
(b)	**Forage crop rotations**	**Green fodder yield Quintals/ha**
(i)	Northern, Central and Western Region	
	Bajra+Cowpea-Sorghum -*Senji*	900
	Sorghum + Cowpea - Maize - Berseem	1250
	Maize + Cowpea - Chinese Cabbage-Sorghum	900
	Maize + Sorghum Multicut-Chinese Cabbage	1200
	Sorghum Multicut-*Berseem*	1300
	Cowpea + Sorghum - Maize + Cowpea	1200
	Maize + Cowpea-Sorghum (Single cut)-Oat	1200
	Napier *bajra* hybrid + *Berseem*	2100
	Napier *bajra* hybrid + Lucerne	1600
	Napier *bajra* hybrid + Cowpea (summer) + Cowpea (Monsoon) -Berseem	2000
	Maize + Cowpea-*Berseem* + *Sarson*-Sorghum + Cowpea	1600
	Napier *bajra* Hybrid + *Guar*-Lucerne	2200
(ii)	Eastern region	
	Bajra + Cowpea-Maize + Cowpea-Oats	1000
	Maize + Cowpea-*Jowar* + Cowpea-*Berseem* + *Sarson*	900
	Maize + Ricebean-*Barseem* + *Sarson*	1100
	Maize + Cowpea-Maize + Cowpea-Maize + Cowpea-Oats	1250
(iii)	Southern region	
	Napier *bajra* hybrid + Hedge Lucerne	2000
	Sorghum + Cowpea-Maize + Cowpea-Maize + Cowpea	1200

7.2 Cropping Scheme

7.2.1 Definition of Cropping Scheme

(i) It is the plan according to which the crops are raised on individual plots in the fixed period in order to get maximum return from each crop without impairing the fertility of the soil

(ii) It is a plan prepared in advance with the objective of getting maximum income from the farm with minimum expenditure and without reduction in the soil fertility.

7.2.2 Principles of Cropping Scheme

The selection of crop, framing of crop rotation and their allocation to individual plots for a particular period are the main technical problems in planning a cropping scheme. Cropping scheme should be planned based on certain principles given here.

(i) It should be formulated according to the size of the farm and availability of labour

(ii) It should be prepared according to the source of irrigation and domestic needs.

(iii) Cropping scheme should be based on source of capital which includes building, farm machinery and bullock power

(iv) Cropping scheme should be such that it may provide employment to the labour throughout the year

(v) The plan of the cropping scheme should be according to the resources, disposal of the produce and nearness to the market.

(vi) Only those crops, for which the cultivation practices are well-known, should be included in the cropping scheme

(vii) New varieties and other new technologies should be adopted for testing in a limited area at the beginning.

(viii) Area under various crops should be kept equal year after year.

(ix) Due consideration should be given to the government policies while selecting crops for inclusion in the cropping scheme.

(x) Forage crops should be included in the cropping scheme as per requirement of fodder

(xi) Cash crops should invariably be included in rotation.

(xii) Cropping scheme should include crops according to the market demand.

(xiii) It should not be of more than three to four years

(xiv) The framing of rotation should be according to the principles of crop rotation as per domestic need

7.2.3 *Advantages of Cropping Scheme*

(i) Good cropping scheme provides maximum employment of labour throughout the year.

(ii) All domestic needs are met from the farm

(iii) Maximum return is obtained if crops are selected according to their demand

(iv) Labour, fertilizer, seed, machinery and facility for irrigation at the farm are arranged in advance.

(v) The income likely to be accrued is known in advance.

7.2.4 *Preparation of Cropping Scheme*

Following points should be kept in mind while preparing cropping scheme

(i) Area under layout should be about 10 per cent of the total area of farm.

(ii) Fertility status of the soil should be known.

(iii) Irrigation, fertilizer and labour requirements and their resources should be known

7.2.5 *Calculation of Cropping Intensity*

Following points have to be considered in calculating the area under crops

(i) Area under fallow or green manure is not included for finding out the cropping intensity

(ii) Only half area of each crop is included in calculating the area from mixed cropping

$$\text{Cropping intensity} = \frac{\text{Total cropped area}}{\text{Net area}} \times 100$$

Example

Prepare a cropping scheme of a farm of 10 hectares situated near to the city of Hisar in Haryana and having canal and tubewell irrigation The annual rainfall of the area is 400mm. The soil of the farm is sandy loam having 66 per cent sand, 22 per cent silt and 12 per cent clay, 10 per cent area will be utilized for farm office and stores. Calculate the cropping intensity. Refer Tables 7.1 and 7.2.

Crop-rotation :

(i) *Bajra* - Wheat
(ii) Cotton - Wheat
(iii) *Bajra* - Wheat - Moong
(iv) *Chari* - *Berseem*
(v) Maize - Maize - *Berseem*
(vi) Cowpea - *Chari* - *Berseem*
(vii) Bhindi - Potato - Onion
(viii) Til - Gram
(ix) *Bajra* - *Toria* - Sunflower

Table 7.1: Skeleton for Cropping Scheme

Area (ha)	*Kharif*	*Rabi*	*Summer*
1.0	*Bajra*	Wheat	
2.0	Cotton	Wheat	
1.0	*Bajra*	Wheat	*Mung*
0.5	Multicut *Chari*	*Berseem*	
0.5	Maize	*Berseem*	Maize
0.5	*Chari*	*Berseem*	Cowpea
1.0	*Bhindi*	Potato	Onion
1.0	*Til*	Gram	
1.5	*Bajra*	*Toria**	Sunflower

9.0 ha

Table 7.2 Summary Table : Total Cropped Area of the Farm

Sl.No	*Crops*	*Kharif area (ha)*	*Rabi area (ha)*	*Summer area (ha)*
1	*Bajra*	1 + 1 + 1.5	-	-
2	Wheat	-	1 + 2 + 1	-
3	Cotton	2.0	-	-
4	*Mung*	-	-	1.0
5	*Chana*	0.5 + 0.5	-	-
6	*Berseem*	-	0.5 + 0.5 + 0.5	-
7.	Cowpea	-	-	0.5
8	Maize	0.5	-	0.5
9	*Bhindi*	1.0	-	-
10	Potato	-	1.0	-
11	Onion	-	-	1.0
12.	*Til*	1.0	-	-
13	Gram	-	1.0	-
14	*Toria*	-	1.5	-
15.	Sunflower	-	-	1.5
		9.0	9.0	4.5

Total cropped area of the farm = 9.0 + 9.0 + 4.5 = 22.5 ha

$$\text{Cropping intensity of farm} = \frac{\text{Total cropped area}}{\text{Net area of the farm}} \times 100 = \frac{22.5}{9} \times 100 = 250\%$$

QUESTIONS

1 Write the definition and principles of crop rotation.
2 What factors should be considered while formulating good crop rotations? Write in detail about them
3 Classify crops in relation to crop rotation and write forage crop rotation suitable for Northern India
4. What are the merits and demerits of crop rotation?
5 Define cropping scheme What are the principles for the preparation of a suitable cropping scheme?
6 Write in short about the following '
   (i) Advantages of cropping scheme
   (ii) Major points for formation of cropping scheme
   (iii) Precautions in the calculation of cropping intensity
   (iv) What is cropping intensity and how it is calculated?

CHAPTER 8

Irrigation and Drainage

8.1 Irrigation

FOR successful raising of crops, plants should be supplied with water as per their needs. The water requirement of crops is partially met by rains or ground water. The irrigation to the field is necessary to maintain optimum soil moisture balance suitable for a crop variety, its cultural practices like hoeing and weeding, application of fertilizers and pesticides, preparation of field for sowing and for early ripening and ease of harvesting by digging. Irrigation is also necessary for reclamation of saline soils and protection of crops from high temperature and frost. Only some percentage of entire water used for irrigation serves the real purpose of irrigation as considerable part of it is lost in conveyance, deep percolation and seepage in the field

8.1.1 Definition

(i) *Irrigation* . The artificial application of water to the soil for supplying moisture essential for production of crops, especially under stress conditions is termed as irrigation.

(ii) *Water Requirement* : Water requirement is the quantity of water required by the crops from land preparation to their maturity. This also includes losses in water due to evapotranspiration plus the unavoidable losses in water during irrigation.

8.1.2 Advantages of Irrigation

(i) Irrigation has a tremendous effect on production and productivity of various crops.

(ii) Irrigation increases the efficiency of inputs and crop insurance against both short and long spell of droughts.

(iii) Irrigation is an important practice for raising multiple crops and remunerative crops in an area

(iv) Development of infrastructure for irrigation provides employment to labour.

(v) Irrigation provides an opportunity to grow trees on the periphery of fields, roads and canals which lead to less soil erosion and minimizes pollution and generates additional source of income.

(vi) Cheap hydel electricity is obtained from multipurpose irrigation projects.

8.1.3 Disadvantages of Irrigation

(i) Irrigation is a costly proposition as it involves huge money for development of various required infrastructures

(ii) Inefficient use of water results in problems of water logging and salt imbalance which make the lands unproductive or less productive or problematic

(iii) Irrigation through sewerage and canal generates a lot of weeds, and salt problems which affect crop production.

(iv) Preparation of boundary, temporary field and plot bunds and channels for irrigation reduces the effective area for sowing of crops.

(v) Problems of insectpests and diseases in plants are more in irrigated areas than in unirrigated areas.

8.1.4 Factors Affecting Water Requirement of Crops

Evaporation and transpiration affect water requirement of various crops depending upon climatic factors, soil conditions and type of crops. 'Evaporation' is a process during which a liquid changes into a gas, whereas 'transpiration' is a process by which water vapours leave the living plant body and enter the atmosphere. The various factors determining the water requirement of crops and frequency of irrigations and downward movement of water in the soil are given below :

(i) *Climatic Factors* : Temperature, relative humidity, wind velocity, period and intensity of light.

(ii) *Soil Factor* : Soil moisture, soil structure, organic matter, presence of salts, soil acidity, soil colour and its temperature.

(iii) *Plant Characters and Cultural Factors* : Type and stage of crops, root development, leaf area, biotic factors, irrigation method, irrigation frequency and cultural practices such as seed rate, hoeing and weeding, fertilizer application, harvesting schedule, etc.

8.1.5 Critical Stage for Irrigation of Crops

There are certain stages in the lifespan of a crop when their water need is maximum and such stages are called 'critical stages' Hence, crops should invariably be given irrigation at these stages, otherwise their growth and development are adversely affected and production is reduced The critical stages for irrigation of some major crops are given in the Table 8.1.

Table 8.1: Critical Stage for Irrigation of Some Crops

Crop	*Critical stage*
Wheat	1 Crown root initiation 2 Tillering stage 3. Jointing stage 4 Flowering stage 5 Milk stage 6 Dough stage
Paddy	1. Seeding stage 2. Tillering stage 3 Panicle initiation stage 4 Flowering stage 5 Milk stage
Maize	1 Seeding stage 2. Tasseling stage 3 Silking stage 4 Milk stage

Gram	1	Flowering stage
	2	Podding stage
Rapeseed and Mustard	1	Pre-flowering stage
	2	Siliqua filling stage
Groundnut	1	Branching/flowering stage
	2	Pegging down stage
Cotton	1	Pre-flowering stage
	2	Flowering stage
	3.	Boll formation stage
Sorghum	1.	Seeding stage
	2	Tillering stage
	3	Early boot stage
	4.	After each cut in multi-cut varieties
Berseem	1	After sowing during germination
	2	After each cut/harvest
Oat	1.	Tillering stage
	2	Ear emergence
Grasses	1	After sowing during germination
	2	Tillering stage
	3	After each cut/harvest

(*Source* · Hukkeri and Pandey, 1977)

8.1.6 *Source and Management of Irrigation Water*

The primary source of water for irrigation are rainfall and snow. But they are not available all the year round in all the arable areas wherever required for irrigation of crops at various stages of their growth These two sources are almost replenished each year but these re-charge the other water sources in the earth such as rivers, tanks and wells which are utilized for irrigation at different times for successful raising of crops in various areas throughout the year whenever water for irrigation is most needed. Water for irrigation of crops is trapped from sources like rivers, tanks or wells or by a combination of them.

8.1.6.1 River Irrigation

Number of river irrigation projects are working in India from where water is diverted by constructing barrages, dams, diversion bunds, check bunds and spillway provided with slucie gates to regulate the rate of downstream flow and the height of upstream flow, channelized through mains, distributaries or feeder channels, forming a network of channels distributed in the command area to irrigate vast areas But in river life irrigation system, the water of river stream is lifted to irrigate a limited command area

8 1.6.2 Tank Irrigation

The rain water is collected in large number of small, medium and large size tanks which are dug to store water for multi-purpose local use including irrigation of a definite command area where number of crops are grown on fertile soils in these tank based farming system. Generally water is lifted or released through gravity flow for irrigation However, considerable quantity of water in tanks is lost through percolation, seepage and evaporation.

8.1 6 3 Well Irrigation

Ground water is lifted to the surface by digging shallow and large diameter dug wells or drilling shallow or deep tubewells according to the availability of acquifers

8.1.7 *Principles of Irrigation*

The main principles of irrigation are :

(i) There should be maximum and efficient use of irrigation water so that a given quantity of water could be used to irrigate as much area as possible under crop production

(ii) Water should not be allowed to stagnate even for an hour in the fields of all crops and these should be kept most close to the field capacity except paddy, otherwise it will have a bad effect on crops.

(iii) In order to obtain better efficiency in irrigation the levelling, bunding, partitioning of fields in smaller plots with less wastage of cropped area should be done for proper distribution of water in the root zone

(iv) Loss of water after irrigation should be checked through mulching and weed control

(v) Intensity and interval of irrigation should be based on type of soil and crop, cultivation practices and weather condition

(vi) Irrigation water should be used to such an extent that it does not adversely affect soil aeration, nutrient availability, useful soil bacteria, growth and distribution of roots, etc.

8.1.8 Scheduling of Irrigation

The aspect which concerns most in the management of irrigation is as to when the crops should be irrigated In scheduling irrigation due consideration should be given to soil type, crop and its stage of growth, type of culture and atmospheric conditions. There are many approaches for scheduling irrigation but most commonly used approaches are as follows

(i) Soil-water regime approach for scheduling irrigation should not be considered without taking into account of climatic factors which play great role for the need of water for crops Pan evaporation is used to estimate the quantity of water given by the ratio of irrigation water (IW) to cumulative pan evaporation (CPE) Open pan evaporimeter indicates the consumption of water and thus helps to determine the time of irrigation. All these should be standardized with respect to soil, season, crop variety, agronomic practices along with the intensity of previous irrigation or rainfall and other local effects. Practical experience is very necessary before scheduling irrigation For example wetland paddy needs irrigation when field surface shows hair like cracks or even earlier to this stage.

(ii) Well fertilized and light soils, dense leafy and shallow rooted crops and the crops with underground storage tissues require light but frequent irrigation, whereas deep rooted crops in heavy soils require heavy irrigation at long intervals. Heavy soils with shallow rooted crops require light but frequent irrigation.

(iii) Pre-sowing irrigation should be light as it helps the uniform germination of seeds and crop stand. Light and frequent irrigation helps to establish seedlings, tolerate vagaries of weather like light showers or high wind storms that prevail after irrigation. Light irrigation helps the uniform and early ripening of crops.

(iv) Irrigation should be scheduled at moderate temperature of soil, otherwise there will be great loss of water and injury to the roots due to high temperature. Therefore, field should be irrigated during late afternoon or at night so that plants absorb water by the time dissecting winds blow next day During cold season irrigation should be given during morning hours when the soil starts warming up.

(v) Irrigation should not be given to the grown up crop when winds are blowing as it will result in lodging of the crop particularly under flooded irrigation. First irrigation should always be light to stabilize the soil

(vi) Though frequent irrigation is costlier it helps to increase efficient use of fertilizer and other inputs. But how much water is to be applied in each irrigation? It will depend upon the crop, availability of water for irrigation, capacity of root zone, season, cultural practices and expected rainfall.

(vii) There are some critical periods of water requirement for each crop and if crop experiences stress condition during these periods, there will be reduction in yield. Therefore, irrigation should be scheduled during such critical stages in the lifecycle of the crop When water supply is limited the scheduling of irrigation should be done according to critical stages. This is known as physiological stage approach for irrigation scheduling.

(viii) Plant water status is the recent approach, which should be considered for irrigation scheduling as the plant is good integrator of soil, water and weather factors. Plant water status is generally found out from the measurement of leaf water potential. This approach for irrigation scheduling is known as "Plant water status" approach, however, it is not yet common due to high cost of devices used to measure leaf water potential.

8.1.9 Methods of Irrigation

Methods and systems of irrigation to the crops differ according to soil types, topography, water resources, climatic factors and costs and hence due consideration should be given to these factors for selecting an irrigation method to be adopted. The various methods of irrigation used to irrigate field and orchard crops are elaborated as under

8.1.9.1 Surface Irrigation System

In this method, water from an irrigation channel located at upper reach of the field is directly applied to a part or whole of the field which spreads by gravity flow and as per slope of the land. Surface irrigation is further classified into the following categories.

(a) Free or Uncontrolled Flooding

In this method water is released from a head ditch and allowed to flood over the whole field in an uncontrolled manner. This method is used where a large stream of water is available, field being unlevelled and soil is permeable. This method is generally adopted in wetland rice but huge quantity of water is lost in this system and accumulated in the lower part of the field

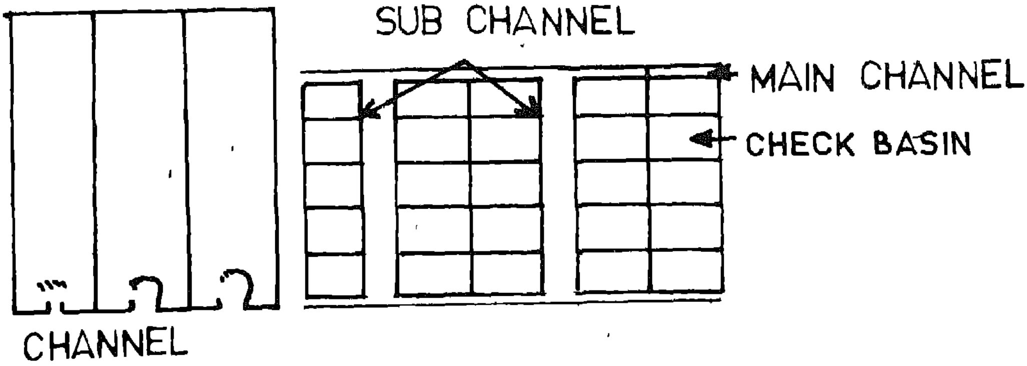
(b) Controlled Flooding

(i) *Border Strip* · In this system (Fig. 8 1) field is divided into a number of long narrow strips of 2 to 10 m width and 10 to 300 m length with small parallel ridges on the sides. Each strip is levelled perfectly and connected with the supply ditch laid out at the upper elevation After irrigation they are disconnected. This method is suited to all irrigatable soils and crops like wheat, barley, oil seeds, pulses, pasture crops and particularly those spaced closely. This method is economical, applicable to all types of soil and allows control over irrigation water But the major limitations of this method are high flow of water, extensive levelling, grading of field and require engineering design for high efficiency in irrigation.

(ii) *Check Basin* : Check basin is the most popular method (Fig. 8.1) used to irrigate the fields in our country. The size of check basin depends on soil type, available stream flow and cultivation practices. Checks varying in size from 10 to 150 sq.m. are used The check basin should be levelled properly. In this method it is possible to apply precise amount of water for irrigation up to field capacity. It is well suited to all irrigatable soils and to a variety of crops. However, potato, tobacco, maize and chillies which are susceptible to saturation of root zone should not be irrigated by this method. Moreover, lot of field area is utilized for making too many ridges and repairing of ridges. Supervision during irrigation is very necessary.

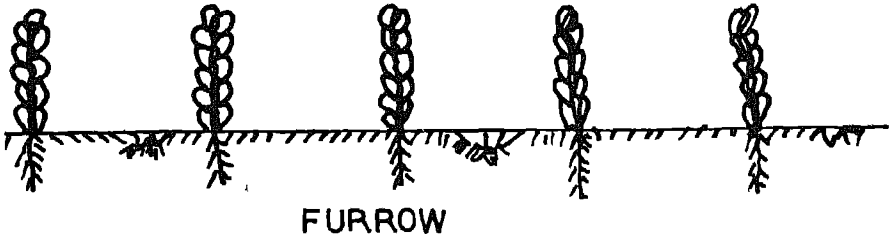
(iii) *Furrow Method*: This method (Fig. 8 1) is used in crops like sugarcane, maize, cotton, potato and tobacco, etc. which are sown in rows and furrows made between the rows of crops. Water is applied in the furrows and tip of the ridge is not directly wetted. The size and shape of furrows should be according to the crop grown, implements, used and spacing between rows. Furrows are made along the slope upto 3 per cent of slope This method reduces losses of water through evaporation and allows faster movement of water It also allows soil to be cultivated immediately after irrigation as part of the soil surface is wetted and both large and small streams can be used by adjusting the furrows. However, velocity of water flow should be given due consideration while designing furrow system of irrigation

(iv) *Basin or Ring Basin* : This method (Fig 8.1) of flooding is just like check method especially used to irrigate widely spaced crops like individual plants. The shape of the ring may be circular or rectangular or square and generally a ring is made around a tree but sometimes 2-5 trees are included in one basin depending upon soil and surface slope. This method considerably economises the use of water. Crops like sweet gourd, pumpkin and ash gourd and orchard crops are irrigated by this method.

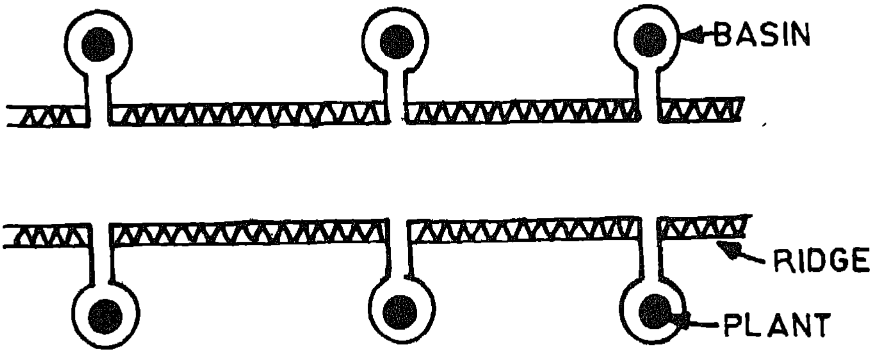


CONTROLLED FLOODING

CHECK BASIN METHOD



DEEP FURROW METHOD



RING OR BASIN METHOD

Fig. 8.1 Surface Irrigation Methods

8.1 9.2 Sub-Surface Irrigation Method

The application of water directly to soil under the surface is known as sub-surface system of irrigation. In this, the water is applied into a series of field ditches deep down upto the impervious layer It then moves laterally and vertically through capillaries and saturates the root zone.

In artificial sub-surface irrigation, perforated or porous pipes are laid underground in the vicinity of root-zone and water under pressure is distributed through these pipes In general, this method consists of field supply channels, ditches or trenches properly spaced in the field and drainage ditches to dispose of excess water This system saves water loss through evaporation and reduces wastage of land It is most suitable for irrigating crops grown on heavy clay soils. But this method involves lot of expenditure and its applicability is limited due to lack of impervious soil layer.

8.1.9 3 Sprinkler or Overhead Irrigation Method

In this method water is applied to the surface of soil or crop in a uniform pattern spraying the same through a sprinkler nozzle. The sprinkler system consists of a pump to lift and convey water under pressure, pipes for conveying of water, the sprinkler nozzle and risers which connect the sprinklers head with a pipeline Sprinkler system is classified into two categories i.e. rotating head type and the perforated pipe type. An area ranging between 3 to 50 hectares can be irrigated by this method depending upon its capacity The main advantages of this system are .

(i) It can be used for all crops except paddy and on all types of soils.

(ii) It is most suited for uneven toporgraphy of soil, problematic soils and where water and labour is scarce.

(iii) Water supply is controlled and uniform and the system is efficient

(iv) Pesticides, weedicides and fertilizers can also successfully be applied by this system.

Its demerits are that it involves high cost, water distribution is influenced by blowing winds, pollination is adversely affected in certain crops and there are mechanical operational problems.

8.1 9 4 Drip or Trickle Irrigation

In this method water is applied drop by drop to the root zone of a crop. This system was designed in Israel by Simca Blass, an irrigation engineer in 1957. This system consists of a pumping unit to lift water and to produce the desired pressure of about 2.5 kg/sq. cm, pipeline of PVC pipes and tubes with drip type nozzles and a filter to purify the water The amount of water coming out from the nozzles can be regulated by varying the pressure at the nozzle and according to the size of the nozzles. Water is lifted and distributed through overhead pipelines which are fitted with nipples to drop water at desirable site

The main advantages of this system are .

(i) Water is used most economically as there is no loss in water due to percolation and evaporation and hence this method is most suited to arid regions

(ii) It allows growing of orchards even on saline soils

(iii) Fertilizer can be applied through solution with irrigation water Nevertheless, initial high cost and maintenance of equipment are the major drawbacks of this system.

8.2 Drainage

Good drainage is very essential for healthy plant growth. The water accumulates in the soil either from rains or seepage from canals, irrigation channels and reservoirs The excess water is lost from the soil through surface evaporation, plant transpiration, running off the surface to rivers and draining through soil to the water table. The draining out of the excessive water from root zone is called soil drainage

Under waterlogged conditions, the soil organisms cannot respire and root growth is restricted Plant nutrients are also not available and even if available, cannot be taken up The rising water table increases salt concentration at root zone which destroys the soil structure Plant growth is drastically restricted in waterlogged soils. The roots of upland plants require oxygen as well as water for proper growth. The concentration of organic acids, phenolic compounds and other toxic substances, increases in the absence of oxygen and directly destroy the plant roots. Drainage has become a problem in the areas where excess water is available for irrigation (Fig. 8.2).

8.2.1 Types of Drainage

The excess water may be disposed through open drains on the surface or through underground drains.

8 2.1.1 Surface Drainage

In area of heavy rainfall good surface drainage should be provided to drain the rain water Surface drainage may be of two types depending upon the availability of water and slope of the land

(i) *Drainage by Beds* . This system is best adapted to large areas of flat lands Some soils have such a compact structure that water will not move down through them into underground drains These soils must be drained by open ditches or drainage by beds (Fig. 8.3) In this system, the field is divided into 20 to 80 metre beds, separated by shallow drain troughs which are generally wide dead furrows. Surface water finds its way down the slightly sloping sides of these dead furrows to a suitable outlet. These furrows must be kept clean so that water flows without obstruction

(ii) *Open Ditches or Drains* Open ditches are probably the simplest and cheapest draining devices but they are often not satisfactory because machinery is hindered by open ditches and ditch banks are good places for the growth of weeds which finally spread over the whole field Drainage ditches on flat lands should be dug a little more deep than is necessary to carry the water, as they will gradually fill up The ditches should be in parabolic shape

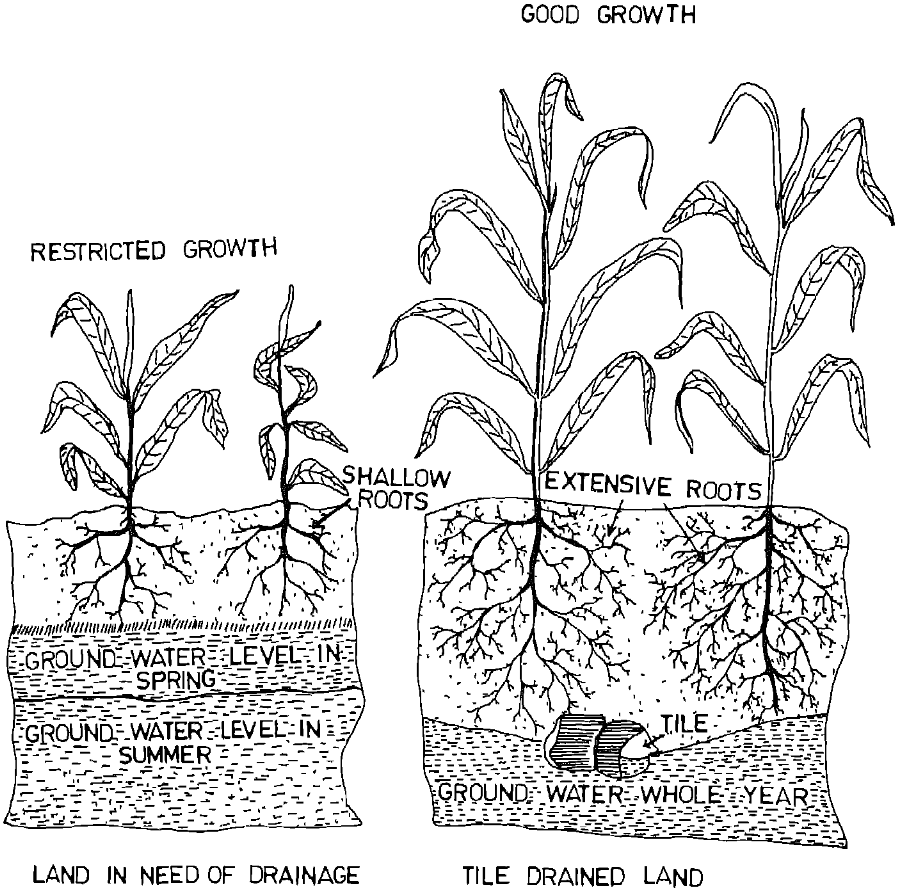


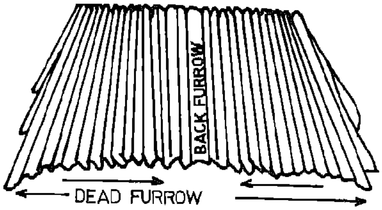
Fig. 8.2 Effect of Drainage on the Growth of Corn Plant

and wide, so that they offer a rapidly increasing cross section to stream flow. The velocity of water in the drains should be maintained at a non-erosive level by proper grading and shaping. The number of drains or ditches depends on the character of soil slope and the intensity of the rainfall. A fall of 10 to 15 cm per 50 metre in the ditches increases the flow of water (Fig. 8.3).

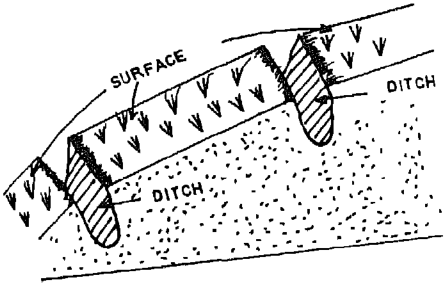
8.2.1.2 Underground Drainage

The excess water flow down through porous layer of earth by gravity force into the underground drains which are generally laid below one to two metres of soil surface. The underground drainage is best suited to lower down the water table or the areas where percolation of water is very high. Earthen pipes, tiles and moles are used to lay out the underground drains. The joints of pipes or tiles are left uncemented so that drainage of water takes place largely through the joint and not through porous body as is usually thought The tiles are tied strongly by a strip of wire to prevent the entry of clay and silt and they are conencted with a shallow well from where water is used for irrigation or disposed to the open drains

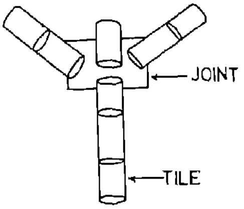
Satisfactory layout of a tile drainage system requires considerable planning and a lot of experience. This system is the most satisfactory but the most expensive than all other drainage systems (Fig 8.3) A tile drainage system will work satisfactorily for a century or more if properly planned, adequately constructed and carefully maintained. The depth and spacing to lay the lines of tile will vary with the crops grown and the types of the soil Soils with slow downward movement of water should have shallower placing of the line of tile, and lines should be laid closer together. In case of sugarcane growing areas of Andhra Pradesh and Tamil Nadu, the farmers use the mole drains. They are made at a depth of 45-60 cm and are quite effective. This depth is also suited for most of the grain and fodder crops.



1. DRAINAGE-BY-BED SYSTEM



2 OPEN DITCH SYSTEM



3. TILE DRAINAGE SYSTEM

Fig. 8.3 Different Drainage Systems

The best suited spacing for the lines of tile are at 60 cm depth and 20 cm apart in clay and clay loam at 90 cm depth and 35 cm apart in silt loam, and at 125 cm depth and 100 m apart in sandy soils.

8.2.2 Precuations in Tile Drainage

(i) Trees near tile line should be cut so that roots cannot grow into the cracks between joints of tiles

(ii) Any depression of tile line indicates broken part of tiles which should be repaired immediately before the whole system is ruined.

(iii) Sometimes rodents or birds live and plug the tiles Precaution should be taken timely and tiles repaired.

(iv) Deep rooted legumes, close growing crops and grasses are specially helpful in improving the drainage capacity of soil

(v) Heavy machinery operation on a wet soil reduces its drainage capacity by creating tillage pans.

(vi) Cattle grazing on wet soil packs the surface soil and thus lowers the efficiency of the drainage system

(vii) Addition of organic matter in heavy soil improves its structure, reduces compactness and increases drainage property of the soil

8.2.3 *Advantages of Good Drainage*

Good drainage helps in maximizing the crop production in the following ways

(i) Improves aeration and structure of the soil.
(ii) Increases organic matter break down in the soil
(iii) Increases soil life
(iv) Improves workability of the soil.
(v) Improves germination of seeds.
(vi) Increases depth of rooting
(vii) Reduces weed infestation
(viii) Increases availability of plant nutrients.
(ix) Increases temperature of soil
(x) Reduces accumulation of harmful alkali salts.
(xi) Decreases plant diseases such as root-rots
(xii) Improves the health of man and animals, because many oarasites are killed on drying of soil
(xiii) Wider adaptation of the drained soil to a greater number of crops.

It is not only enough for individual farmers to see that there is no water collection in their fields but the government should provide permanent open or uderground drains for disposal of water by implemetning pilot projects. The state government should provide loans to individual farmers to purchase centrifugal pumps which are invariably used in draining out the flood water or shallow well water to save cash crops and orchards or gardens from damage.

QUESTIONS

1. Define irrigation What are its principles, advantages and disadvantages?
2 Enumerate the various factors affecting water need of crops. Describe the critical stages of irrigation in crops like wheat, *berseem* and sorghum.
3. What are the various sources of irrigation water and how is their water managed for irrigation?
4 How is the scheduling of irrigation in crops decided? Explain
5. What are the various methods of irrigation Explain sprinkler and drip irrigation systems and their comparative merits and demerits
6 Differentiate between the following
   (i) Irrigation and water, requirement.
   (ii) 'Physiological stage approach and 'plant water status' approach for irrigation
   (iii) Check basin and ring basin systems of irrigation
7 What do you mean by drainage? How does it affect plant growth?
8. What are the precautions taken during the installation of tiles drainage?
9 Differentiate between the following
   (i) Surface and underground drainage
   (ii) Furrow and ditch drainage.
   (iii) Tile drainage and ditch drainage
   (iv) Drainage and irrigation
10 What are the advantages of a good drainage?

CHAPTER 9

Stages of Harvesting and Factors Affecting Losses in Forage Crops

HARVESTING of forage crops at an appropriate stage is a very important aspect of crop management which influences both yield and the quality of fodder to a considerable extent If forage crops are harvested at early stages their fodder yield will be low but quality of fodder will be good, whereas in case of harvesting of forage crops at later stages, their fodder yield particularly dry matter yield will be more, however, there will be tremendous reduction in the quality of the fodder At late stages of harvesting the fibre content in the forage increases and palatability and digestibility are decreased. Therefore, various forage crops should be harvested at an appropriate stage in order to get maximum fodder yield and better quality

9.1 Proper Stages for Harvesting of Forage Crops

The proper stages for harvesting of forage crops are given in Table 9.1.

9.2 Factors for Losses and Their Minimization in Forage Crops

Apart from the stage of harvesting there are a number of factors which affect losses in forage crops. These not only adversely affect the growth of forage crops but cause losses in their yield and quality of fodder. These factors can be divided in two categories i e.

(i) Biotic factors, and

(ii) Abiotic factors.

9.2.1 Biotic Factors

These include various diseases and insect-pests

9 2.1 1 Diseases

Forage crops are attacked by several major and minor plant pathogens The degree of damage due to plant diseases on forage crops determines the quantum of loss in fodder yield and quality. The common pathogens reduce carbohydrates, carotene and crude protein thus affecting the palatability and digestibility of fodder. Foliar diseases reduce the fodder yield as well In our country, the estimates of losses in fodder yield of graminaceous forages like *jowar, bajra* and oat are 50, 30 and 55 per cent, respectively In case of leguminous forages, *guar,* cowpea and clovers, the extent of losses are still higher i.e. 75, 74 and 45 per cent, respectively Various kind of diseases that attack cereal fodders,

Table 9.1 : Proper Stages for Harvesting of Forage Crops

Sl.No	*Forage crop*	*Cutting system*	*Stage of harvesting*
1.	*Jowar*	Single cut	Fifty per cent to full flowering which comes 60, 70 and 90 days after sowing in early, medium and late varieties
		Multicut	
		(i) Instant	Pre-boot stage i e 50-55 days after sowing
		(ii) Subsequent cuts	At 40-45 days interval
2.	Maize	Single cut	Silk to milk stage
3.	Teosinte	Single cut	Pre-tasseling
4	Oat	Single cut	Fifty per cent to full flowering.
		Two cut	
		(i) First cut	Pre-boot stage i.e. 60-65 days after sowing
		(ii) Second cut	50 per cent to full flowering
5.	Cowpea	Single cut	Flowering to initiation of pod formation
		Two cut	
		(i) First cut	Pre-flowering i.e. 45-55 days after sowing.
		(ii) Second cut	Full flowering to initiation of podding
6.	*Guar*	Single cut	Flowering to pod initiation i e about 65-75 days after sowing.
7	*Berseem*	Multicut	
		(i) First cut	50-60 days after sowing.
		(ii) Subsequent cuttings	At 40 days in winter and 30-35 days in spring after previous cut.
8.	Lucerne	Multicut	
		(i) First cut	80-100 days after sowing.
		(ii) Subsequent cuttings	At 30-40 interval
9.	Napier *Bájra* Hybrid	Multicut	
		(i) First Cut	50-60 days after sowing at 4-5 ft height of crop.
		(ii) Subsequent cuttings	At 35-45 days interval depending upon season.
10.	Grasses	Multicut	Cutting schedule varies according to the grass species But in general proper stages for harvesting are:
		(i) First cut/ grazing	At 65-80 days after sowing.
		(ii) Subsequent cuts/grazing	35-45 days after the previous cut/grazing 40-45 days interval depending upon species
11	Pasture legumes	Multicut	
		(i) First cut/ grazing	At flowering stage i e. from 65-80 days after sowing depending upon species.
		(ii) Subsequent cutting/ grazing	40-45 days interval depending upon species

grasses and legume forages are listed in Table 9.2.

9.2.1.2 Insectpests

Insectpests attacking forage crops are many and they cause tremendous damage at various stages of growth resulting in loss in yield and quality of forage. The losses due to insectpests range from 30-40 per cent in *Jowar*, 25-30 in cowpea, 20-35 in *guar* and 30-35 per cent in lucerne. The major pests infesting forage crops are given in Table 9.3.

Forage crops production is also impaired in varying degrees due to attack of different types of nematodepests. The attack of these pests is more in forages grown in tropical and sub-tropical regions throughout the year as such conditions

Table 9.2 : Major Diseases of Forage Crops

Crop	*Diseases*
Jowar	Foliar diseases viz., Oval leaf spot (*Ramulsipora sorghicola*), Leaf blight (*Helminthosporium turcicum*) Anthranose (*Colletotrichum graminicola*), zonate leaf spot (*Gloeocercospora sorghi*), Rough leaf spot (*Aschochyta sorghi*), Grey leaf spot (*Cercospora sorghi*)
Bajra	Downy mildew (*Sclerospora graminicola*), Smut.
Oat	Leaf blotch (*Helminthosporium sp.*), Rust (*Puccinia coronata*), Stem rust (*Puccinia graminis*)
Cowpea	Leaf spot (*Cercospora sp*), Yellow mosaic virus.
Lucerne	Downy mildew, Rust (*uromyces striatus*), Leaf spot (*Pseudopeziza medicagines*)
Guar	Bacterial blight (*Xanthomonas cymopsidis*), Alternaria leaf spot (*Aternaria cyamopsis*)
Berseem	Root rot (*Rhizoctonia sp.*)
Subabul	Yellow leaf spot (*Exosporum leucaena*), Pink disease (*Corticum salmoni color*), Yellowing of leaves (*Fusarium solani*).

Table 9.3 : Major Insectpests of Forage Crops

Crop	*Insectpests*
Jowar	Shootly (*Atherigona soccata* Rondani), Stem borer (*Chilo partellus* swinhoe)
Maize	Stem borer (*Chilo partellus*)
Gaur	Leaf perforator (*Dichomeris ianthes* Meyr.)
Cowpea	Jassids (*Empoasca motti* Pruthi), Hairy caterpillar (*Spilosoma obliqua* Walker)
Berseem	Gram pod borer (*Heliocoverpa armigera* Hubner), Army worms (*Spedoptera litura sp.*)
Lucerne	Lucerne welvil (*Hypera postica*)
Grasses	Alfalfa aphid (*Therioaphis maculate*), Grasshopper (*Chrotogonus* sp.)
Pasture	Same as in case of above.
Legumes	cultivated legume fodders

provide favourable opportunities for their multiplication resulting in severe damage to forage crops.

9.2.1.3 *Weeds*

Number of weeds emerge in the field of forage crops and cause greater loss in their fodder yield than do insectspests and diseases. Weeds generally grow faster than forage crops and compete with them for plant nutrients, space, light and moisture. Weeds cause heavy losses in dry matter yields of forages in general and cultivated forages in particular i.e. loss in dry matter yield of sorghum due to weeds is to the tune of 54 per cent. List of major weeds affecting forage crops is given in Table 9 4.

Table 9.4: Major Weeds of Forage Crops

Annual
- (a) Rainy season
  - (i) Grassy weeds
    - Jangle rice (*Echinochloa colonum*)
    - Makra ghas (*Dactyloclenium aegyptium*)
    - Crab grass (*Digitaria sanguinalis*)
  - (ii) Broad leaf weeds
    - Jungli cholai (*Amaranthus viridis*)
    - Patharchutta (*Trianthema portulacastrum*)
    - Kari-gandhari (*Digera arvensis*)
    - Tunaki (*Tridax procumbens*)
- (b) Winter season
  - *Bathua* (*Chehopodium almum*)
  - Banmethi (*Melilotus alba*)
  - Sand weed (*Spergula arvensis*)
  - Annual Medic (*Medicago denticulata*)
  - Krishan neel (*Anagallis arvensis*)
  - Hirankhuri (*Convolvulus arvensis*)

Perennial
- Motha (*Cyperus rotundus*)
- *Doob* (*Cynodon dactylon*)
- Kans (*Sacchrum spontaneum*)
- Wild carrot weed (*Parthenium hysterophorus*)

To minimize the losses in yield of forage crops due to infestation of weeds the field should be kept free of weeds by manual weeding but it is costly and time consuming. However, mechanical weeding is not possible due to dense population and closer spacing in forage crops. Hence, weedicides can be used to overcome the infestation of weeds and yield losses particularly in the monsoon season

9.2.2 *Abiotic Factors*

There are many abiotic factors like water stress, water logging and alkalinity, salinity and acidity in soils which determine as to which forage crops should be grown under these conditions Weeds grow in excess on such soils and compete with forage crops for nutrients resulting in poor growth and reduction in yield and quality of forage in various crops. The effect of various abiotic factors on forage crops is elaborated here

9.2 2.1 *Water Stress*

When water supply does not meet the requirement of forage corps, water stress develops in the plant This adversely affects the growth of forage crops, the production and the quality of fodder. The effect of water stress depends upon the crop species and variety on one hand and the magnitude and time of occurrence of water deficit on the other. The manner in which water deficit affects the forage yield varies with growth stage. Crops like *berseem,* oat, maize, cowpea and teosinte are very sensitive to water deficit and there is considerable loss in the fodder yield of these crops due to drought. Forage crops like *jowar, bajra* lucerne, barley, pasture grasses and legumes are less sensitive to water stress and hence these crops should be grown in dryland areas to reduce the losses in fodder yield of these crops due to drought. Adoption of silvipastoral system is more useful under these conditions to augment fodder resources

9.2 2.2 Waterlogging

Excess of soil water results in poor respiration of roots and drastic reduction in photosynthesis of forage crops Excess water causes more losses in leguminous than in non-leguminous forages because the bacteria present in the root nodules of leguminous forages stop working and die under waterlogged conditions. Forage crops growing in waterlogged soils have shorter and thicker roots The growth of forage crops is reduced. As soon as water recedes, roots are not able to grow fast and plants thus are left with insufficient root surface to absorb enough nutrients and water This ultimately causes major damage to roots resulting in setback to the growth of crops and loss in fodder yield. However, in advanced stages cereal forages can tolerate waterlogging for about 10-12 days In order to overcome the hazardous effect of excess water condition, higher seed rate than normal should be used.

Seed should be placed at shallow depth and sowing time should be advanced. Seed soaking before sowing is necessary for quicker and better germiantion. *Panicum coloratum* variety sabi, Rhodes grass (*Chloris guyana*), Paragrass (*Brachiaria mutica*), Buffel grass (*Cenchrus ciliaris*), Blue panic (*Panicum antidotale*) and Teosinte can tolerate water for about 15 days and give better fodder yield under these conditions as compared to other cereal fodders. To minimize the loss in fodder yield other grasses such as Ruzi grass (*Brachiaria ruzezensis*), Signal grass (*Brachiaria decumbens*), Columbus grass (*Sorghum almum*), *Phleum pratense*, *Phleum repens*, Nandi grass (*Setaria sphacelata*), *Dactylis glomerata* and Karnal grass (*Diplachne fusca*) should be grown under waterlogged conditions as these are tolerant to excess water and moisture.

9.2.2.3 Alkaline, Saline and Acidic Soils

Forage crops show remarkable variation for their adaptation and performance under alkaline, saline and acidic conditions of soils Alkaline, saline and acidic soils not only cause reduction in yield but also in quality of fodder in various forage crops. Leguminous forages are more prone to losses than non-legume forages in these types of soils Therefore, forage farming in these areas should be based on local varieties adapted to these conditions The loss in forage production can also be reduced by the use of forage crops/varieties having tolerance to above types of problematic soils. Forage crops suitable for growing in various kinds of soils are given in Table 9.5.

Table 9.5: Forage Crops Suitable for Problematic Soils

Soil type	*Forage crops*
Saline	Karnal grass (*Diplachne fusca*), Para Grass (*Brachiaria mutica*), *Panicum clandestinum*, *Panicum laevifolium*, *Sporobolis marginatus*, *Cyndon dactylon*, Bahia grass (*Paspalum notatum*), *Urochloa mosambicensis*, *Chenopodium album*

	Glycine Javanica and Stylosanthes humilis
Alkaline	Rhodes grass (*Chloris guyana*) and Paragrass (*Brachiaria mutica*)
Acidic	*Pennisetum polystachyon, P pedicallatum*, Kikiyu grass (*P clandestinum*), Bahia grass (*Paspalun notatum*), Centros *Desmodium intortum, Stylosanthes guianensis.*

Alternatively soil amendments like gypsum in alkaline and lime in acidic soils could be used to minimize the adverse effect of these soils on productivity of forage crops.

9 2.2.4 Marginal and Sub-Marginal Lands

Raising of forage crops on marginal and sub-marginal lands is uneconomical due to their poor production potential on such lands. These lands are poor in major nutrients like N, P and K which are essential for proper growth and expression of yield potential of forage crops. Their availability and supply to the plant greatly influence the production and quality of fodder in forages. Nitrogen has maximum effect on growth of non-leguminous forages while phosphorus has the maximum effect on legume forages. The growth of forage crops can also be regulated by bio-regulants Excess nitrogen in the soil results in abundant nitrate in the plants which may be harmful to livestock.

Micro-nutrients like Fe, Mn, and Zn are found in reduced form in the soil are also harmful to the growth of forage plants leading to reduction of fodder yield and increase in toxicity effects. Therefore, adequate use of fertilizers and micro nutrients is desirable for better growth of forage crops and to reduce the loss in forage yield and quality thereof.

QUESTIONS

1. Define harvesting stage and its importance in forage crops What are suitable stages of harvesting of single cut fodder crops?
2. What do you mean by multicut forages? List the appropriate stages of harvesting multicut forages.
3. List the biotic factors and discuss their role in causing loss to forage crops.
4. What are abiotic factors causing loss to forage crops and how can the adverse effect of problematic soils be minimized?
5. Write the effect of water logging on forage crops

CHAPTER 10

Seed Production of Forage Crops

SEED is a basic and most important input for enhancing production in forage crops Number of high yielding cultivars of forage crops have been developed and recommended for growing in different parts of the country. The main factor, due to which not much impact of improved varieties on forage production could be realized, is the non-availability of required quantity of quality seed. The use of quality seed enhances the fodder yield of various forage crops

10.1 Definition of Seed

Botanically, seed is a matured embryo which produces next generation and is used for sowing Seed is any propagating material or part of plant which has the potential to produce economic crop of the plant. The quality seed shall comprise of 100 per cent genetic purity, high physical purity standards, high germination and vigour potential.

10.2 Seed Production Constraints in Forage Crops

(i) Low seed production ability of most of the varieties in majority of forage crops.

(ii) Poor management of forage crops for seed production as no one applies recommended quantity of inputs.

(iii) Forage crops are generally grown on poor and neglected pieces of land for their seed.

(iv) Lot of damage to the seed crop of *jowar*, maize and *bajra* is done by the birds when grown in isolation.

(v) Cross pollinated forage crops need more isolation distance which often becomes difficult to provide.

(vi) Some clovers and luceine are self-compatible which are pollinated by insects. The population of insects and their activity is influenced by weather conditions.

(vii) Diseases and insectpests cause heavy damage in seed production of crops like sorghum, *berseem* and lucerne.

(viii) Seed production in forage is uneconomical.

(ix) Most of the grasses and few of the clovers are poor seed setters.

(x) Whatever quantity of breeder seed is produced, the same is rarely multiplied up to foundation and certified seed stage Thus, the proper chain of multiplication of seed is broken in forages

10.3 Classification of Seed

10.3.1 Breeder Seed

Breeder seed is the seed or propagating material which is produced directly under the supervision and control of plant breeder and provides source for the foundation seed. Breeder seed should be genetically pure in order to guarantee to conform prescribed standards of genetic purity

10.3.2 Foundation Seed

Foundation seed is the progeny of breeder seed or it can even be produced from foundation seed Foundation seed produced directly from breeder seed is designated as foundation seed stage-I, whereas foundation seed produced from foundation seed stage-I will be designated as foundation seed stage-II It shall meet specified genetic identity and purity so as to conform certification standards prescribed for the crop variety under certification

10.3.3 Certified Seed

Certified seed is the progeny of foundation seed and its production is handled in such a manner so as to maintain specific purity and genetic identity to conform to the certification standards specified for the crop/variety under certification

10.4 Considerations for Seed Production

Following factors should be given special importance while planning of seed production in forage crops

10.4.1 Use of High Yielding Varieties

Tremendous variation in the seed production ability has been observed in various varieties of forages This problem is not much in case of oat, maize, and teosinte as most of the varieties of these crops give almost similar seed and fodder yield But in case of *jowar* there is lot of variation in seed productivity of different varieties for example varieties like *SSG 59-3, SL44* and *M P. Chari* are poor seed yielders, whereas other varieties *HC 136, PC6, PC23, U P. Chari 1 and 2, HC 171* and *HC 260* have high yield of both seed and fodder In case of lucerne, *Anand-2* gives much higher seed yield than *T-9* Cowpea varieties *Russian Giant* and *EC 4216* give higher seed yield than other varieties of this crop.

10.4.2 Selection of Location

Seed of various crops cannot be produced economically at all the locations in the country. Suitable areas for production of various categories of seeds are given in Table 10 1

10.4.3 Climate

Climatic factors like rainfall, temperature, wind velocity and relative humidity play a great role in the seed production of forage crops If *jowar* is grown under irrigated conditions and rainfall of 200-300 mm, it gives high seed yield Under rainfed area rainfall of 600-700 mm is needed for good seed yield of *jowar*. For *bajra,* cowpea and *guar* and most of the grasses and legumes rainfall ranging from 350 to 500 mm is optimum. All the monsoon season crops need high temperature, medium humidity and less wind velocity *Rabi* forages like *berseem,* lucerne and oat need slightly high

Table 10.1: Seed Production Area for Forage Crops in India

Crops	*Centre*	*Regions*
Cowpea	Anand, Hyderabad Coimbatore, Hisar Ludhiana and Jhansi	Gujarat, Andhra Pradesh Tamil Nadu, Haryana Punjab and Uttar Pradesh
Sorghum	Hyderabad, Akola Parbhani, Indore Jabalpur, Coimbatore Jhansi and Surat.	Andhra Pradesh, Maharashtra Madhya Pradesh, Uttar Pradesh Tamil Nadu and Gujarat
Bajra	Ludhiana, Hisar, Anand Durgapur, Nagpur and Hyderabad	Punjab, Haryana, Gujarat Rajasthan and Andhra Pradesh
Maize	Ludhiana, Karnal, Delhi Udaipur, Hyderabad and Bangalore	Punjab, Haryana, Delhi Rajasthan, Andhra Pradesh and Karnataka
Oat	Hisar, Ludhiana Pantnagar, Anand Jhansi and Durgapura	Haryana, Punjab, Uttar Pradesh Gujarat and Rajasthan.
Berseem	Ludhiana, Gurdaspur Amritsar, Jallandhar Kapurthala, Hisar Pantnagar, Jabalpur and Jhansi	Punjab, Haryana, Uttar Pradesh and Madhya Pradesh
Lucerne	Surat, Neemuch, Udaipur Ferozepur	Gujarat, Madhya Pradesh Rajasthan and Punjab.
Pasture legumes	Hyderabad, Bangalore Rahuri, Madras and Jhansi	Andhra Pradesh, Karnataka Maharashtra, Tamil Nadu and Uttar Pradesh,
Tropical grasses	Jodhpur, Jhansi, Hisar and Hyderabad	Rajasthan, Uttar Pradesh Haryana and Andhra Pradesh

temperature, less humidity, no rainfall and minimum wind for their high seed yield.

10.4.4 Isolation

This aspect is most important from genetic purity of the seed. Therefore, due attention should be given while selecting a field for seed production of a variety so that proper isolation distance from any other variety of the same forage crop is maintained. The isolation distances for seed production for various forage crops are given in Table 10 2

10.4.5 Genetic Purity

Cross-pollinated or often cross-pollinated forage crops like sorghum, maize, *bajra*, teosinte, lucerne, *berseem* and other clovers are more liable to genetic impurity due to

Table 10.2 : Isolation Distance for Seed Production in Forage Crops

Crops		*Isolation distance in metre*	
		Foundation seed	*Certified seed*
Jowar	(i) Hybrids	400	200
	(ii) Varieties	200	100
Maize		400	200
Bajra		1000	200
Oat		30	10
Cowpea		10	5
Guar		10	5
Berseem		200	150
Lucerne		1000	500
Grasses		1000	500
Pasture legumes		30	20

out crossing. Moreover, modern methods of harvesting, processing, bulk drying and storage have increased chances of mixture in the seed if due care is not taken in these operations Following factors are most important to maintain the genetic purity of the seed for getting higher production of forage.

10.4.5.1 Seed Source

To raise a good seed crop, it is must to use the seed of proper class and from a proper source. This kind of seed will have high purity and germination as compared to seed from market.

10 4 5.2 Preceding Crop

Repeated cropping of the same field with same crop is never advisable because the dropped seed of previous crop can germinate and thus create severe problems for genetic purity of seed variety and loss to seed crop. In such circumstances crop rotation should be followed.

10.4.5.3 Roguing in Seed Plots

Another source of genetic contamination is the presence of off-types. The causes of off-types are .

(a) Presence of recessive character in heterozygous condition in the variety.

(b) Volunteer plants arising from seed produced by earlier crop.

Therefore location or site to grow seed crop must be taken care of. Various weeds like Johnson grass in *jowar, Hirankhuri* in oat and cuscuta in lucerne and off-type plants from the field of seed crop of these forages should be removed before flowering

10.5 Agronomic Management of Forage Crops for Seed Production

In addition to the type of variety, agronomic practices like seed rate, time and method of sowing, application of fertilizer and irrigation, weed control and stage of harvesting for seed have tremendous effect on seed yield of forage crops

10.5.1 Soil and Its Preparation

The forage crops for seed production should be raised on soils which are not infested with various types of weeds and soil borne diseases. Seed production should not be taken up on saline, alkaline and acidic soils.

Sandy loam to loam soils with good irrigation and drainage are most suitable for raising a good seed crop of majority of forages.

The field selected for seed production should be ploughed after pre-sowing irrigation three to four times in criss-cross fashion with harrow or cultivator and planking should be done to prepare a fine seed bed. Weeds on bunds all around the field should invariably be removed before or after sowing

10.5.2 Time of Sowing

Optimum time of sowing is the first requisite for obtaining higher seed yield in forage crops However, sowing time varies from crop to crop and region to region. *Jowar* for seed production should be sown from second fortnight of June to first week of July, whereas maize, *bajra,* teosinte and grasses may be sown for seed purposes in the first fortnight of July. Cultivated monsoon season leguminous crops like cowpea, *guar* and rice bean should be sown from 10th to 20th July for their higher seed yield. Pasture legumes for seed can be sown in rainy season from July to mid August. In case of rabi fodders, oat for seed should be sown from mid October to November, *berseem* from end of September to November and lucerne in whole of October to mid November.

10.5.3 Seed Rate and Spacing

Optimum plant population has considerable influence in increasing seed yield. *Jowar,* Teosinte, Maize, *Guar* and cowpea should be sown in lines at 45 cm distance using seed rate of 20 kg, 30 kg, 20 kg and 25 kg per hectare, respectively. *Bajra* is sown in rows having 30 cm distance and the seed rate of three to four kg per hectare is enough Grasses and pasture legumes are planted at 45 cm distance in rows. The seed rate varies from 3-5 kg in grasses and 10-12 kg in case of legumes. Plant to plant distance of 10-15 cm should be maintained in all the cereal fodders, except oat, *guar,* and cowpea by thinning the extra plants.

The seed rate and spacing for seed crop of oat are the same as for fodder. Lucerne for seed production is sown in rows at a distance of 45 cm using four to five kg seed per hectare. The seed rate and method of sowing of *berseem* for seed are the same as for fodder Sowing of all above crops for seed should be done by methods as described for fodder production.

10.5.4 Manures and Fertilizer

In case of all perennial forage crops 20-25 tonnes of farmyard manure should be applied in the field before ploughing Cereal fodders and grasses respond well to nitrogen while legumes to phosphorus application, 50-60 kg N and 60-80 kg P_2O_5 per hectare is sufficient for higher seed yield in most of the cereal fodders and grasses However, in case of cowpea, *guar* and *berseem* apply 20 kg N/ha and 60-80 kg $P_2 O_5$ depending upon soil test. Lucerne crop gives higher seed yield when 120 kg P_2O_5/ha is applied. In case of pasture legumes the use of 50 kg P_2O_5 increases the seed yield tremendously.

10.5.5 Micro-Nutrients and Growth Regulators

Micro-nutrients and growth regulators also play an important role in increasing the seed yield of forage crops. Micro-nutrients like zinc, molybdenum, manganese, iron and boron have been quite effective in enhancing the seed yield in different forges depending upon their deficiency in the soil. Cycocel at 40 ppm, a growth retardant, limits the vegetative growth in cereal forages and promotes their seed production Spray of Cytozyme at 1,500 ml/ha and planofix at 40 ppm in both *berseem* and lucerne are quite effective for increasing their seed yield.

10.5.6 Irrigation and Weed Control

Application of irrigation is one of the basic needs to obtain higher seed yield in forage crops. Properly irrigated crops also produce bolder seed. The irrigation is particularly important when one cut is taken for fodder Irrigation in all these crops should invariably be given after cutting the crop for fodder. In oat three irrigations at initiation of tillering, jointing and milk stage are sufficient for seed production All the forage legumes except *berseem* and lucerne should be irrigated at full bloom Irrigation after last cut and thereafter at fortnightly intervals gives higher seed yield in *berseem* Lucerne crop for seed production should not be irrigated after full flowering otherwise its seed yield will be adversely affected.

There is no difference in weed control methods for fodder and seed production in forage crops However, obnoxious weeds like *Cuscuta* in *lucerne*, *hirankhuri* in oat and *kasni* in *berseem* should be removed from the seed crop before the flowering of these weeds.

10.5.7 Cutting management

Certain forage crops like cereal fodders except maize, grasses, *berseem*, lucerne and pasture legumes have good regeneration after cutting and hence their seed production after taking few cuttings for fodder will be more economical and losses due to lodging will also be avoided. *Jowar, bajra* and oat give as much seed yield after one cut as in case of without cut and the seed thus obtained is bolder with excellent germination. First cutting in these crops should be taken at pre-boot stage and then crop may be left for seed No cuttings in *berseem* and lucerne crops should be taken after 10th to 20th March in order to get higher seed yield in these crops Grasses should be left for seed production twice in a year i e in September and then in February till then cuttings can be taken After taking number of cuttings pasture legumes should be left for seed in the month of March.

10.5.8 Plant Protection Measure

Midge is the most serious pest of sorghum earheads. Maggots of this pest feed on ovaries of the flowers affecting the settings of seed adversely If incidence of this pest is serious, spray the earheads at 50 per cent flowering in the crop with Endosulfan 30 EC at one litre or Malathion 50 E.C. at one litre in 500-600 litres of water per hectare Spray should be repeated if midge infestation persists. Monocrotophos 36 E.C. should be sprayed at 0.04 per cent to check the leaf hoppers and lucerne weevil for higher seed yield in lucerne The gram pod borer (*Heliothis armigera*) affecting *berseem* crop at bud stage can be controlled through the spray of Thiodane at one litre in 500 litres of water on the crop at the bud stage.

There is attack of grain smut in seed crop of *jowar* To save the crop from this disease, certified seed should be used and the affected plants should be uprooted and burnt or buried. Certified seed crop and foundation seed crop should not have more than 0.05 and 0 1 per cent plants affected with this disease, otherwise seed crop is rejected. Green ear, erget and smut are major diseases of earhead in *bajra* Ergot and smut in *bajra* can be controlled by spraying one kg of difolatan in 50 litres of water per hectare at boot stage Covered smut and loose smut are the important diseases which affect the panicle of oat. These diseases can be controlled by treating the oat seed with ceresan at 2.5 kg per ha before sowing.

10.5.9 Harvesting and Threshing of Forage Crops, Seed Yield and Its Storage

Different varieties in various forage crops differ in their maturity for seed Seed crop of all forages should be harvested when their seed is fully matured The harvested crop should be threshed by labourers or suitable threshers. Seed yield of forage crops like *jowar*, *bajra*, maize, oat cowpea, *guar*, rice bean, *berseem*, lucerne, grasses and pasture legumes under proper management range from 10-15, 8-10, 25-30, 18-20, 10-15, 12-16, 12-15, 4-6, 3-5, 4-5 and 10-15 quintals per hectare, respectively The seed should be cleaned and graded with seed cleaners and graders and then stored properly at about 10 per cent moisture

QUESTIONS

1. Define seed. What are the different classes of seed?
2. Write constraints of seed production in forage crops
3. What are the major considerations in production of quality seed? Explain genetic purity of seed
4. What is the role of suitable locations for seed production of various forage crops? List the locations most suited for forage crops seed production
5. Write important agro-techniques for seed production of forage crops.
6. Write short notes on .
   - (i) Role of growth regulators in seed production
   - (ii) Cutting management in relation to seed production
   - (iii) Role of quality seed in forage production.
   - (iv) Seed yields in forages.

CHAPTER 11

Conservation of Fodder and Its Importance

DURING lean months of May and June in summer and October, November and December in winter, green fodder is not available. As the same time during February-March and July-August-September plenty of surplus green fodder is available. This surplus can be conserved for feeding animals during the scarcity periods. Plenty of green foliage is also available during monsoon season in the forests which can be preserved for future use for feeding the animals Generally, fodders are not preserved by the Indian farming community The Indian farmer is illiterate and lacks knowledge of fodder conservation and other latest methods of processing of different fodders with a view to improve their nutritive value for feeding dairy animals The surplus green fodder available in peak seasons during February, March and July, August, September may be converted into 'Hay' and/or 'Silage' The dried 'hay' may be baled for easy storage and transportation from one part to another part of the country. The conserved fodder can substitute costlier grains in dairy rations for economical milk production.

11.1 Methods of Conservation

There are two methods for conservation of fodder

1. Silage making.
2 Hay making.

11.1.1 Silage

Silage is the material produced by the controlled fermentation of a crop of high moisture content. It is a 'pickled green fodder' which is made in order to preserve forage for a period of time and to feed it to livestock during scarcity period or any season of the year. It is a rich source of carotene. Plant materials (grasses and legumes) can be preserved in the form of silage, which is a good source of feedstuff for dairy animals.

The quality of silage is improved if fodder is cut and used at the right stage of plant growth. The aroma of the silage is sometimes used to judge its quality. A strong butyric acid odour (like rancid butter) is not desirable. On dry matter basis, grass silage is almost equal in feeding value to hay An efficient anaerobic fermentation, resulting in more lactic acid production, is a pre-requisite of good quality silages.

Silage is also an efficient feed because there is little waste when it is fed to animals. If storage is a problem, silage offers the additional advantage of being highly compact. The feeding value of any silage depends on method of its preparation.

11.1.1.1 Merits

(i) At a low expense silage furnishes high quality succulent and palatable feed during lean periods or any other period

(ii) Crops may be ensiled when weather does not permit curing them into hay

(iii) Silage even from plants with coarse stalks such as maize, *bajra* and sorghum is eaten practically without wastage.

(iv) Weedy crops which could make poor hay may produce satisfactory silage Ensiling process also destroys many kinds of weeds.

(v) The crop from given area can be stored in less space as silage than as dry fodder.

(vi) Forages are cut from the field in a day or two Thus, ensiling gives sufficient time for land preparation for the next crops.

(vii) Use of silage permits the keeping of more stock on a given area of land.

(viii) Silage preserves the nutritive value of green fodders and hence avoids spoilage of surplus fodder.

11.1.1.2 Demerits

(i) Silage is spoiled if proper procedure of making it is not adopted.

(ii) There are some nutrient losses (10-15 per cent) in silage making.

(iii) Silage making is laborious and costly.

(iv) It cannot be transported and marketed

11.1.2 Hay Making

Green fodders when dried to about 85 per cent dry matter is called hay and it preserve most of its nutrients including carotene A good hay must keep the characteristic green colour of the crop from which it is made. It should be prepared in such a way that there is less loss of leaves due to shattering The hay should be free from extraneous matter like fungus, mould and weeds The aroma of the hay should be such that it is relished by the dairy animals It should not have more than 15 per cent moisture so that it can be stored safely without risk of fermentation and combustion.

11.1.2.1 Merits

(i) Green fodder can be stored as hay which can be used during scarcity period of green fodder in summer and winter months

(ii) With the timely cutting of *berseem* and lucerne for hay making, more cuttings of the fodder can be obtained which result more nutrients production per unit land.

(iii) The land is vacated earlier for next sowing as the standing crop is harvested for hay making in a single day.

(iv) It provides nutritious fodder throughout the year and provides cheaper substitute for concentrates.

(v) Daily expenditure on harvesting the fodder crop is avoided

(vi) Hay can be transported from one place to another. It can also be marketed.

11.1 2.2 Demerits

(i) There are nutrient losses in hay making which depends upon the type of method used for making hay

(ii) It is somewhat costlier.

(iii) The hay is spoiled in storage if it is not properly dried and stacked

11.2 Importance of Hay and Silage

The nutrients in a feeding stuff enable the animal body to maintain energy to perform the vital processes of life and provide the material to replace the essential tissue break down which occurs in the body continuously. Food also provides the constituents and the energy required for growth and production.

In feeding dairy animals, forages are the cheapest source of nutrients and should be used as much as possible Cows and buffaloes consume large quantities of forage when it is of good quality. If a farmer produces good quality fodder, it will not be necessary to feed large amounts of concentrate for economical milk production. The amount of forage a cow eats depends on quality of forage, size of the animal and amount of milk production A cow will eat about 1.5 kg hay equivalent in the form of poor fodder for each 100 kg live weight per day, 2 kg of average fodder, 2.5 kg of good fodder and 3 kg of excellent fodder.

A high milk producing dairy cow or buffalo requires a high energy intake. While feeding poor quality roughage with low energy content to a dairy animal, more energy must come from expensive concentrates. Good quality hay and silage have a higher protein and carotene and comparatively lower fibre content Animals fed on good quality hay or silage consume larger quantities and hence they are more efficient in terms of economic production. It has been observed that a cow or buffalo yielding upto seven to eight kg of milk daily can be maintained on high quality fodder or its silage alone

11.3 Feeding of Hay and Silage

Economically feeding schedule for a cow/buffalo weighing 400-450 kg is as under·

(a) Yielding milk upto three to four kg milk/day

(i) Maize + cowpea silage - 30 kg and wheat straw - 3 kg

(ii) Oat silage - 30 kg and wheat straw- four to five kg.

(iii) *Berseem* + wheat straw silage - 30-35 kg.

(iv) Maize + lucerne silage - 30-35 kg and wheat straw - 3-4 kg.

(v) Hybrid napier silage - 25 kg, wheat straw - four to five kg and oil cake - 1 kg

The above rations may be supplemented with 25g of common salt and 30g of mineral mixture. Each combination supplies about 0 5 kg DCP and 6 kg TDN and 10 5 kg dry matter. One kg concentrate may be added for additional production of 2-3 kg of milk.

(b) Yielding milk upto seven to eight kg/day.

(i) Maize + cowpea silage - 30 kg and *berseem* or lucerne hay - 5 kg.

(ii) Oat silage - 25 kg and *berseem* hay - 7 kg.

(iii) *Berseem* + oat silage - 30-35 kg and cowpea hay six to seven kg

(iv) Maize silage - 35-40 kg and *berseem* hay - 6 kg

(v) Hybrid napier silage - 25 kg and lucerne hay - 7 kg

The above rations should be supplemented with 25-30g common salt and 35g of mineral mixture. Each combination has 0.75 kg DCP, 7.2 kg TDN and 11.5 kg dry matter approximately

The nutrient requirement of the milch animals producing more than 8 kg of milk cannot be met by the fodder alone due to limitation of intake One kg concentrate may be added in the ration for additional production of two to three kg of milk

(c) For feeding heifers

(i) *Berseem* hay - 4-5 kg and concentrate mixture - 1 kg.

(ii) Maize or oat silage - 12-15 kg and concentrate mixture - 1 kg.

(d) Bullock-doing normal work

(i) Maize silage - 25 kg and concentrate mixture - 2 kg.

(ii) *Berseem* + oat silage - 25-30 kg and concentrate mixture - 1 kg

(e) Young calves-two to five kg silage or one to two kg good quality hay should be made available to the young calves along with 0 5 kg concentrate about 6 months of age.

11.4 Soilage

Green fodders are usually cut and fed to animals immediately The fresh cut green forages are called soilage It is an effective way of improving the nutritive value of the poor quality fodder like wheat *bhusa* when mixed with green fodder and fed to the animals. Green forage feeding has the disadvantage that a forage crop may not always be available at the proper stage for feeding to dairy animal

11.5 Haylage

Haylage is a low moisture silage (40 to 50 per cent moisture) and is made from grass/or legume that is wilted to 40-50 per cent moisture content in the field before ensiling. It is similar to silage except it is lower in moisture.

QUESTIONS

1 What is the importance of fodder conservation?
2 Define silage? Give its merits and demerits.
3 What is hay? Give its principle of making, merits and demerits
4 Write the importance of the feeding of hay and silage to dairy animals
5 Fill in the blanks
    (i) Silage is preserved by the formation of__________acid
    (ii) Ensiling is the name of a__________
    (iii) Weedy crops can also be converted into good__________
    (iv) There are__________methods of fodder conservation
6 Differentiate between haylage and soilage

CHAPTER 12

Silage Making

WELL prepared silage is highly palatable and digestible. Animals, fed on silage, usually eat more roughage on dry matter basis. The acidity of silage does not produce any adverse effect on animals. There are three main criteria for achieving natural preservation of crops. These are :

(i) an adequate amount of fermentable carbohydrates in the crops,

(ii) the presence of a suitable microbial population, and

(iii) the ability to achieve and maintain anaerobic conditions in the silo Ensilage is the name given to the process, and the container is called silo

12.1 Kinds of Silos

The silage can be prepared in silo tower, silo pits, bunkers, trench and plastic bags. In our country silo pits are generally used, which may be *kacha* or *pucca* according to the economic status of the farmers. Being a permanent farm structure, a silo should be *pucca* constructed to withstand long usage. The advantages of such silos are :

(i) durability,

(ii) minimum spoilage, and

(iii) very well adapted to automation (loading and unloading machinery).

The silos can be classified as follows·

12.1.1 Tower Silos

Tower silos are generally circular in shape and equipped with a number of doors at different heights. These are closed as the silo is filled and opened at the time of removal of silage.

12.1.2 Pit Silos

This is constructed by digging a pit in the soil and it resembles a well. This type of silo can be square, rectangular or circular and made only in place where the water table is low enough so that the silo will not fill with water (semi-arid regions). In comparison to tower silos, pit silos have some more advantages : (i) they are not damaged by storm and (ii) require less reinforcing.

12.1.3 Trench Silos

At a comparatively low cost this type of silo can be constructed quickly. It is most popular in areas where the weather is not too severe and where there is good drainage. Trench silo is completely below the soil surface. The greatest advantage of these types of silos are that they could be either cemented for earthen structure and are quite spacious Large quantities of forage material can be conserved at a time, and thus handling cost is reduced Compression of forages could be done most efficiently with tractors. However, it requires comparatively large space.

12.1.4 Bun Silos

These do not have any definite structure. On hard, flat and smooth surface, a polythene sheet is spread and material to be ensiled is spread over it layer after layer. Each layer is sufficiently pressed with the help of tractor. The top is covered with a polythene sheet. Ends of the lower and upper polythene sheet are twisted and a thick layer of soil is kept on the twisted portion to maintain anaerobic condition

12.1.5 Bunker Silos

As a labour saving measure, bunker type of silos are constructed above the ground usually with concrete floors. Bunker silos are generally catching the attention of many farming community.

12.2 *Pre-Requisite of Ensiling*

In order to obtain silage of high quality, the forage crop should have the following qualities.

(i) It must be neither too dry nor too high in water content. If it is too dry, it will not pack well and enough air will remain, which will permit the development of mould. If forage is too high in water, there will be more losses due to effluents. Forage should have 30-40 per cent dry matter content at the time of ensiling.

(ii) Forage should contain sufficient sugar (8-10 per cent soluble carbohydrates) for the development of enough acid in silage. It will check the development of undesirable bacteria.

(iii) Solid stem crops pack well and small amount of air is left in the mass

12.3 Crops and Their Stage for Silage Making

Graminaceous crops such as maize, *jowar*, sudan grass, *bajra*, hybrid napier and oat are most suitable for ensiling Leguminous crops such as lucerne, *berseem* and cowpea are not suitable for silage making, but after giving some treatments they may also be converted into good quality silage.

Stage at which forage is cut profoundly influences the quality of silage produced. Most grasses should be cut after the heads have emerged. Lucerne should be cut at early flowering stage and *guar* and cowpea soon after their first seed pods have filled. Oat, maize and *jowar* should be cut at mid or early dough stage.

The physical stage of the crop also affects the quality of silage. The packing of chaffed forage will be better than the unchaffed one. There is also much more rapid lactic acid fermentation due to the early release of cell sap.

12.4 Ensiling Methods for Non-Leguminous Fodders

12.4.1 Ensilage without Additive

Graminaceous crops such as maize, *jowar*, *bajra*, hybrid napier, sudan grass and oat are most suitable for ensiling without any additives All these graminaceous crops have sufficient amount of soluble carbohydrates to produce enough lactic acid for preservation. However, addition of 1per cent urea at the time of ensilage enhances nitrogen content of the silage

12.4.2 Ensiling with Additive

The objective of using additives is to ensure greater certainty in producing silage of good quality The homogeneous mixing of such additives with the ensiled material is prerequisite to their successful use

12 4.2 1 Carbohydrate Additives

Attempts have been made to promote lactic acid fermentation by adding carbohydrates to the ensiled material. Molasses have been found to be effective in many experiments, but it was found less satisfactory with wet material It is recommended that molasses should be added at a rate of 3-4 per cent by weight, diluted with equal parts of water and sprayed Normally, about half the sugar in the molasses remain unchanged in the silage and the silage made with molasses is of good palatability. Silage of good quality has been obtained with dried whey, dried beet pulp and hexoses as additives Addition of starch in the form of cereal grains has also given good results

12.4 2.2 AIV Method

The principle underlying AIV method is to check undesirable fermentation by reducing the pH to less than 4 0 through lactic acid fermentation which provides sufficient acidity. This method is named after AIV Virtanin who suggested the use of lactic acid itself as an additive. It is, however, uneconomical in practice Later on AIV acid was used consisting of a mixture of H_2SO_4 and HCl and is applied to silage after dilution in water (1 part acid per 6 parts water) to give 2N solution. This solution is used at a rate of about 7 litre per 100 kg green. In practice the method is not popular, as farmers do not like to handle inorganic acids. Moreover, the mineral acid may be injurious to the health of the animals and the silage is not very palatable AIV silage produce hypomagnesaemia and tetany in cows

A neutralizing mineral mixture, consisting of 30 per cent sodium bicarbonate, 30 per cent ground lime, 30 per cent sodium diphosphate and 10 per cent dicalcium phosphate should be fed at a rate of 75g per 10 kg AIV silage

12 4 2 3 Use of Other Inorganic Acids

In addition to the normal AIV mixtures of HC1 and H_2SO_4 proposed by Virtanin, other acidic additives have been tested including H_3PO_4 acid mixtures (HC1 + 1% H_3PO_4), penthester salt ($PC1_5$), SO_3, Biosil (H_2SO_4 absorbed in a powder). The use of acid salts is based on the same principle as the AIV method

12 4 2.4 Use of Formic Acid

Formic acid is used as 1.20 aqueous solution and 7 litre solution per 100 kg ensiling material is normally recommended. Formic acid preserves the quality of protein up to certain extent The formic acid silage has given good results when fed to dairy cows and beef cattle. No evidence of any danger of injurious effects resulting from the use of formic acid have been reported. However, it is also a costly affair.

12 4.2 5 Other Additives

Several salts such as sodium sulphite, calcium formate, sodium sulphate and ammonium bisulphate were used as additives at the rate of 0.5 to 1 per cent but the results were inconsistent. This may be due to difficulties involved in mixing thoroughly the small amount of salt with ensiling material. This is also not generally practised.

12.5 Silage from Legume Fodders

When ensiled alone most legumes tend to produce unsatisfactory silage, if ordinary methods are followed This is due to the following reasons :

(i) Lack of sufficient sugars in legumes

(ii) High moisture content.

(iii) High buffering capacity due to higher protein content.

Legumes can be ensiled successfully by the following simple methods.

12.5.1 Wilting

Silage can be made from legumes if they are wilted to a dry matter (DM) content of 35 to 40 per cent. Wilting for 1 to ½ days before ensiling will bring the desired dry matter and will reduce the water content which will consequently increase the sugar content in the forage

12.5.2 Mixing with Non-Leguminous Forages

Non-leguminous forages such as maize, sorghum and oats are rich in soluble sugars. When mixed with legumes, they will supply the required quantity of sugar for proper fermentation. This type of silage will also be rich in both energy and protein. The forage should be wilted for one day to increase the dry matter content and must be chaffed before ensiling.

12.5.3 Mixing with Straws

Wheat *bhusa* along with chaffed leguminous green fodder (*Berseem*, lucerne, cowpea) in the ratio of 1.3 or 2.5 can be successfully ensiled. This method not only helps supply of preserved fodder but also increases the utilization of wheat *bhusa* by 25 per cent The average dry matter digestibility is also increased.

12.6 Silage from Wheat Bhusa

Wheat *bhusa* can also be ensiled after enrichment with nitrogen and readily available energy source. The ensiling material is mixed in the ratio of wheat *bhusa* 43.0, molasses 15, urea 1.5, minerals mixture 0 5 and water 40.

12.7 Size and Capacity of Silo Pit

A good silo should have air tight walls and the corners should be rounded up for better packing of forage and efficiency excluding the air from the mass It should have sufficient depth. The silo may be above or below the ground depending upon the water table. To avoid losses of nutrients to some extent *pucca* pit should be used. If *kutcha* pit is used, some lining should be used to fill air pockets in the walls and bottom. The quantity of settled silage is about 15 kg per cubic feet space The size of the silo depends on .

(i) number of animals to be fed,

(ii) period for which to be fed,

(iii) quantity of silage to be fed per animal per day, and

(iv) availability of quantity of fodder.

Keeping these factors in view, farmers can utilize silo pits of any of the following sizes as outlined in Table 12.1.

Table 12.1 : Dimensions of Silo Pits

Length (ft)	*Width (ft)*	*Depth (ft)*	*Capacity (qtls)*
5	5	6	22 5
10	5	6	45 0
15	5	6	67 5
20	5	6	90 0
25	5	6	112 5

12.8 Filling and Sealing of Silo Pit

12.8.1 Filling

In case of *kutcha* pits, the walls and bottom should be thoroughly plastered with mud before filling the pit Plastic sheet should be placed along with sides as well as at the bottom of the pit to prevent direct contact of green fodders with the earth.

The chaffed (2-3 cm) fodder should be filled layer-wise and every layer should be nicely tramped to exclude as much air as possible (Fig. 12 1). Towards the top of silo material should be tramped especially near the walls. Exclusion of air is essential to avoid mould growth and heat production in the silo The fodder in silo should be filled two to three feet high so that the top will be well above the ground level after setting (Fig 12.2). This is necessary because during the process of fermentation a good deal of shrinkage takes place

12.8.2 Sealing

Side walls are used mainly to protect the silage from air, thus preventing waste A considerable amount of waste, however, can occur on the surface of the silage, unless some material of sealing is used

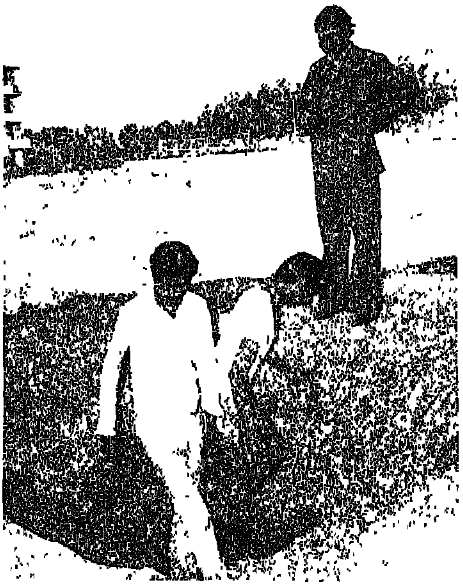


Fig. 12.1 Filling of Silo Pit

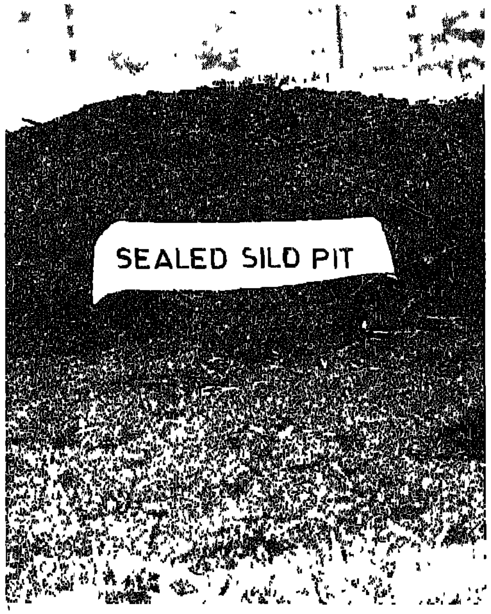


Fig. 12.2 Sealing of Silo Pit

The materials of sealing used are. soil, ground chalk, farmyard manure or saw dust.

A reasonable thickness of the sealing materials should be used (10-15 cm) and the sealing should be done as soon as filling of silo has been completed.

As the silage settles, there is tendency for air pockets to form between the silage and the seal and it is, therefore, worthwhile to press the seal occasionally for a week after it has been applied.

Plastic sheet has been used successfully in controlling surface waste, but it is essential that this cover should be made entirely air tight This means that edges of the sheet must be carefully embedded in the soil, so that the air cannot get under the sheet

12.9 Opening and Feeding of Silage

12.9.1 Opening

The silage should be opened after 50 to 60 days of filling After opening, it becomes necessary to feed a pit completely A. 5-10 cm layer of silage must be removed daily Spoiled mouldy silage should always be discarded. For all animals only as much silage should be supplied as is required at each feeding. Care should be taken to remove any waste, because it spoils in a short time on exposure in the air.

12.9.2 Feeding of Silage

The approximate quantity of silage to be fed to the dairy animals is given in Table 12 2.

Table 12.2 : Quantity of Silage to be fed to Different Categories of Dairy Animals

Types	*Quantity of silage per head per day (kg)*
Milch cows	25-30
Bulls	20-25
Pregnant cows	15-20
Heifers	10-15
Buffaloes	30-35
Young calves (above 6 months)	2-5

12.10 Chemical Composition and Nutritive Values

The chemical composition and nutritive value of different silages is given in Tables 12 3 and 12.4.

12.11 Losses during Ensilage

Average dry matter losses from fresh herbage ensiled without additive is about 15-17 per cent and those from wilted herbage the losses are 12-13 per cent. However, the dry matter losses range from 1 per cent to 40 per cent. As these losses represent the most digestible fraction of the forage there is considerable reduction in nutritional value of the product as dry matter losses are quite high. The losses which occur during ensilage can be classified into four main categories 1. field, 2. respiration (aerobic), 3. fermentation (anaerobic) and 4 effluent losses.

12.11.1 Field Losses

When crop is cut and ensiled the same day the losses are not more than 5 per cent In some cases even gain in dry matter have been observed. This may be due to photosynthesis which continued for some time even after harvesting. During longer

Table 12.3 : Chemical Composition of Silage Made from Different Fodder (% DM Basis)

Sl.No	*Name of silage*	*CP*	*EE*	*CF*	*NFE*	*Ash*
1	Maize (*Zea mays*)	7.9	1.0	25.0	55.1	11.5
2	Oat (*Avena sativa*)	7.8	1.5	40.8	40.2	9.7
3	Teosinte (*Euchlaena maxicana*)	6.2	4.0	32.0	47.4	10.4
4.	Guinea grass (*Pannicum maximum*)	5.0	1.5	38.9	44.6	10.0
5.	*Jowar* (*Sorghum vulgare*)	6.0	2.0	37.0	45.0	10.0
6	Spear grass (*Heteropogon contortus*)	7.0	1.9	34.8	45.1	10.2
7.	Dal grass (*Hymenachne amplonicaulis*)	7.0	2.0	27.8	44.4	17.8
8.	Sisham leave (*Dalbergia sissoo*)	4.2	3.3	26.5	51.4	14.6
9	Rice straw (*Oryza sativa*)	5.5	1.7	30.4	51.4	11.0
10.	Wheat straw (*Triticum aestivum*)	4.2	0.3	41.7	41.8	13.0

Table 12.4 : Percentage of Chemical Constituents, Nutrients Digestibility and Nutritive Value of Different Fodders and Their Silages

	Chemical composition					*Digestibility coefficient*					*Nutritive value*	
	DM	*CP*	*EE*	*CF*	*NFE*	*DM*	*CP*	*EE*	*CF*	*NFE*	*DCP*	*TDN*
Sorghum	35.10	3.85	1.86	27.00	60.59	57.30	59.38	63.60	48.17	61.90	2.29	54.92
Sorghum silage	30.95	5.20	3.50	31.70	49.50	52.10	38.62	86.55	62.23	51.90	2.06	54.41
Sorghum + Cowpea	29.56	8.31	1.90	33.80	53.21	54.49	62.78	40.27	60.93	60.00	5.22	56.36
Sorghum + Cowpea silage	38.40	7.43	2.56	33.25	42.56	57.05	57.21	51.58	63.69	51.61	4.25	50.45

DM = Dry Matter CP = Crude Protein EE = Ether Extract CF = Crude Fibre
NFE = Nitrogen Free Extract DCP = Digestible Crude Protein TDN = Total Digestible Nutrients

period of wilting, losses in dry matter range from 6 to 10 per cent. During wilting considerable proteolysis also occurs. Sometimes dry matter losses, more than 20 per cent occur in bad weather.

12.11.2 Respiration Losses

Plant enzyme activity will continue in the soil as long as conditions are aerobic and the pH is not drastically altered Respiration will mainly affect soluble sugars.

Generally the silos contains air and grass in the proportion of 2:1 with moderate consolidation. The sugar loss through oxidation in a fodder crop of 20 per cent DM would be 0.30 per cent. The heat produced during oxidation increases the temperature of the mass The increase in temperature is generally 2 to 5 per cent in the silage and depends on rate of respiration, degree of insulation and specific heat of ensiled materials. The respiration losses could be up to 2 per cent of dry matter.

12.11.3 Fermentation Losses

Average fermentation losses of DM ranges from 2 to 10 per cent. In high moisture silage, the DM losses can be even more than 15 per cent Soluble sugars and amino-acids are the main substrates for fermentation process

12.11.4 Effluent Losses

The volume of effluent produced from a silo is influenced mainly by the DM content of the ensiled crop, although other factors such as type of silo, crop, degree of compactness, moisture content, etc., also have their effect. The crops ensiled at about 30 per cent DM produce little effluent

The inevitable losses of dry matter are about 8 per cent while avoidable losses vary between 8-40 per cent (Table 12 5).

Table 12.5 : Nutrient Losses During Ensiling

Types of losses	*Extent*	*Remarks*
Respiration losses	1 - 2	Unavoidable
Fermentation losses	3 - 5	-do-
Effluent losses	4 - 5	-do-
Secondary fermentation	0 - 5	Avoidable
Aerobic transformation	0 - 15	-do-
After fermentation losses	0 - 8	-do-
Total conservation losses	8 - 40	Both

By taking proper care and by using suitable technology, the above losses in ensilage could be minimized to a great extent. However, if proper care is not taken at the time of ensiling and after opening the silo dry matter losses may be up to 40 per cent.

Silage is a high quality succulent fodder available at cheaper cost. Ensiling permits conservation of crops at a time when weather does not permit hay making and the field is to be vacated in the shortest period for next crop. More fodder in less space is stored than as dry fodder. Nevertheless care should be taken that respiration, fermentation, effluent and other losses are minimum These losses can be minimized by preparing the silage from forage harvested on the same day and having about 30 per cent dry matter content and following the standard techniques and methodology of silage making as mentioned above

12.12 Factors Affecting the Quality of the Silages

12.12.1 Dry Matter

The material to be ensiled should have a dry matter content between 30-35 per cent. If the moisture content is very high then there is undesirable fermentation with the result that more of butyric acid is formed instead of acetic and lactic acids. If the dry matter of the crop is high then the material does not compact well with the result more air is entrapped and mould may grow in such silages

12.12.2 Nature of Fodder Crop

The species and the stage of maturity of the fodder crop ensiled affect the feeding value of the silage.

The silage quality depends upon the production of lactic acid which, in turn, depends on the soluble sugars present in the fodder crop. Therefore, fodder crops like maize, *bajra,* oats, *jowar,* etc. are excellent for silage making whereas protein rich crops like *berseem*, cowpea, lucerne, etc are not good for silage making as they are deficient in soluble sugars.

12.13 Precautions in Silage Making

(i) Enough fodder should be available at the site of silage making.

(ii) The silo pit should be filled, compacted and covered as early as possible

(iii) Silage quality also depends on the ensiling technique and hence proper procedure should be followed

(iv) There should not be extraneous materials like iron pieces, nails, weeds, poisonous plants, etc.

(v) There should be proper drainage near the silo.

(vi) Silage should be fed after milkings, as silage feeding during milking or just before milking may add undesirable odour to the milk

(vii) Mouldy silage, if found on the top and sides of the silo, should be discarded

(viii) Once a silo pit has been opened, it should be fed until empty otherwise, undesirable spoilage may take place due to exposure.

QUESTIONS

1 What are suitable crops and their harvesting stages for silage making?
2. Explain the losses occurring during ensiling
3. How are straws converted into silage?
4 What are the various types of silos?
5. Write short notes on :
    (i) pre-requisite of silage making.
    (ii) Feeding of silage to different categories of animals
    (iii) Making silage from succulent fodder.
    (iv) Precautions during silage making
    (v) Filling of a silo pit
    (vi) Additives used in silage making.
    (vii) Factors affecting the nutritive value of silage

CHAPTER 13

Silage Quality

THE term 'silage quality' is used to denote, not the feeding value but, the extent to which the silage fermentation has proceeded in desirable manner. The main objectives in making good quality silage by the natural process of silage fermentation are (i) to limit respiration in order to reduce nutrients losses and (ii) to stimulate the formation of lactic acid so as to prevent a butyric acid fermentation and thus break down of proteins. The desirable type of silage should have low pH value. It should also be relatively free from butyric acid

13.1 Classification of Silages

The two main microbiological criteria of effective preservation are inhibition of *Clostridia* and fungi as the latter need, the presence of oxygen for better growth The presence of butyric acid is a useful indicator of *Saccharolytic clostridial* activity. While presence of volatile nitrogen is an indication of *Proteolytic clostridia*

Most silages may be grouped under one of the three heads according to the temperature reached in the green mass

13.1.1 Cold Fermentation Silage

In this process the aim is to keep the temperature below 30°C and this is achieved by rapid filling and tight compaction of the crop during a short period of time Good silage can be prepared by this process.

13.1.2 Low Temperature Process

Silage made at temperatures ranging between 30-40°C may be grouped under low temperature silage For making low temperature silage it is important that the crop should not be allowed to reach full flowering stage and the pit is filled without wilting If wilting of the crop is necessary then low temperature silage is difficult to make unless chopping is done. Silage made by this process will be of very good quality and the losses shall be bare minimum.

13.1.3 Warm Fermentation Process

This type of silage is an undesirable one which mostly results due to the use of mature crops and excessive wilting of the crops prior to filling in the pit The temperature may rise to 50°C or more and leads to quality deterioration

13.2 *Characteristics of Good Silage*

Colour : Bright, green brown or *khaki*, light green, yellow.

Smell : Pleasant or vinegary.

Texture Firm, smooth.

The microbiological examination of silage is of little value in evaluating the silage.

In Germany, a widely used method of grading silage requires determination of lactic, butyric and acetic acid contents along with pH values. It gives the final classification on the basis of scores (Flieg's values). A particular silage is assigned scores according to its pH and fatty acid values as given in Table 13.1 and is graded according to its total score.

If the silage is of very good quality its total score will range between 44-50, if poor it will have not more than 19 points. Similarly satisfactory and moderately made silage will have scores in between 30-36 and 20-29, respectively.

13.3 General Criteria for Silage Evaluation

13.3.1 Very Good Silage

Good Silage is clear, the taste is acidic, with no butyric acid, no moulds and no proteolysis This pH is 3.5-4.2. The amount of ammonia nitrogen should be less than 10 per cent of the total nitrogen content.

13.3.2 Good Silage

The taste is acidic. There can be traces of butyric acid (less than 0.2 per cent). The pH is in between 4.2 and 4.5. The amount

Table 13.1: German Method of Grading Silage

pH	*Points*	*Lactic acid**	*Points*	*Acetic acid**	*Points*	*Butyric acid**	*Points*
3.50 - 3.79	9	Over 60	20	Under 30	10	0.0 - 0 01	10
3 80 - 4 2	10	60-55 1	18	30.1 - 34	9	0 1 - 2 5	9
4 21 - 4 4	9	55 - 50 1	16	34 1 - 38	8	2 51 - 5 0	8
4.41 - 4 6	8	50 - 45 1	14	38 1 - 42	7	5.01 - 10 0	6
4.61 - 4.8	7	45 - 40.1	12.	42 1 - 46	6	7 51 - 10.0	6
4 81 - 5.0	6	40 - 35 1	10	46 - 1 50	5	10 01 - 15.0	5
5 01 - 5 2	5	35 - 30.1	8	50.1 - 54	4	15.01 - 20.0	4
5 21 - 5.4	4	30 - 25.1	6	54 1 - 58	3	20.01 - 25	3
5 41 - 5 6	3	25 - 20 01	4	58 1 - 62	2	25.01 - 35 35.01 - 45	2 1
5 61 - 5.8	2	20 - 15.1	2	62 1 - 66 more	1	45 01 - 55 55 01 - 60	0 5
5.81 - 6.0	1	15 0 and Under	0	Over 66	0	60.01 - 65 65 01 - Over	10 20

* Percentage of total acids

of ammonia nitrogen is in between 10-15 per cent of total nitrogen content

13.3.3 Fair Silage

Silage is mixed with a little amount of butyric acid (0 3 to 0.5 per cent). There may be slight proteolysis along with some moulds. The pH is between 4.5 and 4.8 Ammonia nitrogen is between 15-20 per cent of the total nitrogen content.

13.3.4 Poor Silage

It has bad flavour due to high butyric acid (more than 0.5 per cent) and high proteolysis. The silage may be moudly, less acidic and pH above 4 8 The amount of ammonia nitrogen is more than 20 per cent of the total nitrogen

QUESTIONS

1 Describe the classification of silages.
2. Explain the Flieg system of grading silage
3 Describe the general criteria of silage evaluation
4 Describe the characteristics of a good silage
5. Describe in brief about
    (i) Silage quality
    (ii) Volatile nitrogen
    (iii) Saccharolytic clostridial activity.
    (iv) Very good and poor silage.

CHAPTER 14

Ensiling Process and Biochemical Changes

14.1 Ensiling Process

ENSILING is the name given to the process of silage making. It is a technique to preserve freshly cut forages in the absence of air with or without additives when the green fodder is cut into small pieces and stored in a silo. The living plant cells continue to respire for some time They consume the oxygen in the air present in the silo and give off CO_2 and H_2O with the production of heat. This causes rise in temperature. After aerobic respiration is completed, microbial changes start. The anaerobic condition is favourable for the growth of acid forming bacteria and then multiplication. The sugars are then converted into lactic acid followed by other volatile fatty acids like formic, acetic, propionic and butyric acids The bacterial fermentation ceases when pH falls to 3 5. The protein present in the green fodder is also broken down into amino-acids, amines and ammonia. The ammonia may escape from the silo in gaseous form.

Some of the minerals, like sodium, potassium, calcium and magnesium present in the green fodder may form salt with acids The brown colour in the silage is due to pigment phaeophytin, a magnesium free derivative of chlorophyll. In addition to acids, some amount of alcohol is also formed which combines with acids and gives a characteristic aroma to the silage

Ensiling does not improve Digestible Crude Protein (DCP) and Total Digestible Nutrients (TDN) values in the silage over that of input green forage/roughage (Table 14 1), but maintains to the original value depending on the efficiency of the ensiling operations

The efficiency of ensiling is judged according to the relative proportions of organic acids produced. The greater the ratio of lactic acid to butyric acid the higher is the efficiency. The quality of silage is good if lactic acid is prominent and when butyric acid is predominant, the quality of silage is poor

The fermentation can be controlled in the silos either by encouraging the formation of organic acids (mainly lactic acid) by bacteria on the fresh forage or by direct addition of acids or preservatives. This is done to maintain the anaerobic conditions and to discourage clostridial fermentation

Table 14.1 : Nutritive Value of Green Fodder and its Silage

Crop	*CP*	*EE*	*CF*	*NFE*	*DCP*	*TDN*
Oat green	9.24	1.88	34.82	44.78	6.30	66.70
Oat silage	8.31	2.95	34.95	41.69	4.32	59.47
Maize green	9.34	1.64	24.08	56.07	6.08	62.99
Maize silage	8.34	1.63	25.02	55.49	4.17	62.99
Sorghum green	5.75	1.06	32.30	49.61	3.44	54.03
Sorghum silage	5.47	1.79	32.28	49.85	2.38	49.74

CP - Crude Protein EE - Ether Extract, CF - Crude Fibre, NFE - Nitrogen Free Extract
DCP - Digestible Crude Protein, TDN - Total Digestible Nutrients

which leads to the production of undesirable nitrogenous compounds such as amines.

14.2 Microbial Flora

Aerobic microorganisms fungi and bacteria are the dominant micro-flora in fresh forage. They are replaced by anaerobic micro-organisms such as species of *Bacillus, Clostridium, Escherichia, Klebsiell, Streptococcus, Leuconostoc, Lactobacillus,* and *Pediococcus* as anaerobic conditions develop in the silo.

Yeast also occur in silage and being facultative anaerobe can survive and proliferate in the silage. The lactic acid producing bacteria can grow at 39°C or below, at 30 per cent moisture and at pH around 4.0 under anaerobic conditions The butyric acid producing bacteria grow at 39°C and above in high moisture silage at pH above 4.5 under aerobic conditions. Four genera of lactic acid bacteria (Table 14.2) are present in silage, *Lactobacillus, Streptococcus, Lenconostoc Pediococcus* The desirable species of lactic acidc bacteria could be more fermentative, high in growth rate, acid tolerant and ferment hexosans and pentosans.

In the initial stages, coliforms dominate the microflora, but in the green mass these are soon replaced by *Leuconostocs* and *Streptococci* However, finally *Lactobacilli* and *Pediococci* dominate. They reduce the pH value to about 3.5 - 4.00 and preserve the silage from clostridial activity.

14.3 Biochemical Changes

14.3.1 Soluble Carbohydrates

Glucose, fructose, sucrose and fructosans are the main water soluble carbohydrates in forages. However, for microbial degradation, glucose and fructose are considered to be the main carbohydrates. Sucrose and fructosans are rapidly hydrolysed to the monomers-glucose and fructose in the silage. These can be fermented by various micro-organisms but in silages lactic acid bacteria dominate the fermentation process by making growth conditions inhibitory for other undesirable/unwanted types of bacteria. The fermentation also varies as per the conditions whether the homo-fermentative or hetero-fermentative lactic acid bacteria are dominant

The homolactic organisms under anaerobic conditions form two moles of lactic acid per moles of glucose or fructose fermented. Different steps in the process are Glucose → Glucose - 6-P → Fructose-6-P→ Fructose 1. 6-Di-P→ Glyceraldehyde-3-P→ Pyruvate→ Lactate. Fructose is directly converted to Fructose-6-P The overall process is shown in a of Fig. 14 1

Carbohydrates
1 $C_6H_{12}O_6 + 2ADP \rightarrow 2CH_3CHOHCOOH + 2ATP$
a Anaerobic Fermentation by Homolactic Organisms
1 $C_6H_{12}O_6 + ADP \rightarrow CH_3CHOHCOOH + C_2H_5OH + CO_2 + ATP$
b. Anaerobic Fermentation by Heterolactic Organisms
1 $3C_6H_{12}O_6 + 2ADP \rightarrow CH_3CHOHCOOH + 2C_6H_{14}O_6 + CH_3COOH + CO_2 + 2ATP$
c Xylose Fermentation
1 $C_5H_{10}O_5 + 2ADP \rightarrow CH_3CHOHCOOH + CH_3COOH + 2ATP$

Organic Acids
d Citrate Fermentation
1 $C_6H_8O_7 \rightarrow + H_2O + ADP \rightarrow 2CH_3COOH + COOH + CO_2 + ATP$
2. $2C_6H_8O_7 \rightarrow 2CH_3COOH + CH_3COCHOHCH_3 + 4CO_2$
3 $2C_6H_8O_7 + H_2O + ADP \rightarrow 3CH_3COOH + CH_3CHOHCOOH + 3CO_2 + ATP$.
4. $C_6H_8O_7 + {}_4H \rightarrow CH_3COOH + C_2H_5OH + HCOOH + CO_2$

e Malate Fermentation
1 $C_4H_6O_5 \rightarrow CH_3CHOHCOOH + CO_2$
2 $2C_4H_6O_5 \rightarrow CH_3COCHOHCH_3 + 4CO_2 + 4H$
3 $C_4H_6O_5 + H_2O + ADP \rightarrow CH_3COOH + HCOOH + CO_2 + 2H + ATP$
4 $C_4H_6O_5 + 2H \rightarrow C_2H_5OH + HCOOH + CO_2$

Key to the formulae :
$C_6H_8O_7$ - Citric acid, $C_4H_6O_5$ - Maleic acid, HCOOH - Formic acid, H_2O - Water
CH_3COOH - Acetic acid, $CH_3COCHOHCH_3$ - 3 Hydroxy 2 butanediol, H - Hydrogen
C_2H_5OH - Ethanol, $CH_3CHOHCOOH$ - Lactic acid, $C_6H_{14}O_6$ - Mannitol.
$C_5H_{10}O_5$ - Xylose, $C_6H_{12}O_6$ - Glucose, ADP - Adenosine Di Phosphate
ATP - Adenosine Tri Phosphate, CO_2 - Carbon Di Oxide

Nitrogeneous Components
f Coupled oxidation-reduction reactions (Strickland)
1 Alanine + 2 glycine→ 3 Acetic acid + 3 NH_3 + CO_2
g. Deamination and decarboxylation
1 3 Alanine→ 2 propionic acid + Acetic acid + NH_3 + CO_2
2 Valine → Isobutyric acid + NH_3 + CO_2
3 Leucine → Isovaleric acid + NH_3 + CO_2
h. Decarboxylation
1 Arginine → Ornithine → Putrescine,
2. Aspartic acid → β alanine.
3. Glutami acid → α - aminobutyric acid
4. Histidine → Histamine.
5. Lysine → Cadaverine.
6. Tryptophan → Tryptamine
7 Tyrosine → Tyramine.

Fig. 14.1 Biochemical Changes

Table 14.2 : Lactic Acid Bacteria Present in Silage

Lactic acid bacteria				
Homo-fermentative			*Hetero-fermentative*	
Lactobacillus	*Streptococcus*	*Pediococcus*	*Leuconostoc*	*Lactobacillus*
L. casei	*S faecium*	*P acidilactici*	*L mesentroides*	*L bachneri*
L curvatus	*S lactis*	*P. pentosaceus*	*L citrovorum*	*L viridescens*
L salivarius	*S. faecalis*	*P cerevisaceus*	*L dextranicum*	*L brevis*
L acidophilus				*L fermentum*
L. coryneformis				
L plantarum				

The heterolactic bacteria on the other side produce anaerobically, one mole of lactic acid, one mole ethanol and one mole of CO_2 per mole of glucose fermented. The steps involved are·

Glucose → Glucose-6-P→ 6-P-Gluconate→ Ribulose-5-P→ Xylulose-5-P, Xylulose - 5-P is further splitted into Glyceraldehyde-3-P and Acetyl-P Glyceraldehyde-3-P is converted to lactate via pyruvate and Acetyl-P is converted to ethanol via acetaldehyde. The overall process is as shown in 1. of Fig. 14.1 b.

Heterofermentative lactic acid bacteria ferment glucose and fructose by following slightly different pathways resulting in different ratios of the final products from the two sugars with additional products being produced from fructose, namely, acetate and mannitol in place of ethanol This results in less lactic acid production and thus the efficiency of fermentation is considerably less than that of the homofermentative types of lactic acid bacteria. The changes which fructose undergoes are :

Fructose → Fructose-6-P → Glucose-6P→ 6-P-Gluconate→ Ribulose-5-P→ Xylylose-5-P This further gives rise to lactate and acetate. Fructose can directly be reduced to maennitol The overall process is shown in 2 of Fig. 14 1 b

Pentoses (xylose, arabinose, etc) formed by the action of plant hemicellulases and acid hydrolysis can also be fermented both by homo-and hetero-lactic bacteria to lactic acid and acetic acid The different steps involved are ·

Xylose→ Xylulose→ Xylulose-5-P This further follows the same route as shown above. Arabinose (if present) is first converted to ribulose and then to Ribulose-5-P, which can further be converted to xylulose-5-P. The overall process is as shown in c. of Fig 14.1.

14.3.2 Organic Acids and Buffering Capacity

The buffering capacity of plants or their ability to resist pH change is an important factor in ensiling Within the pH range of 4-6 about 70-80 per cent of the buffering capacity of herbages can be attributed to the anions (organic acid salts, orthophosphates, sulphates, nitrates and chlorides) The buffering capacity, during ensiling, increases as a result of the formation of lactates, acetates and other organic acids. Wilting or the addition of formic acid inhibit the development of undesirable substances

Citrate and malate are the acids commonly present in a wide range of fodders These acids can be dissimilated both by homo-and hetero-lactic acid bacteria by several pathways, resulting in the formation of either neutral acetoin, 2-3-butanediol and ethanol, salts of organic acids (Lactates, acetates + formates) or alkaline cations. The main processes involved may be as shown in d. and e. of Fig. 14 1. It is generally agreed that lactate is formed from citrate via pathway 3. and from malate via pathway 1.

14.3.3 Nitrogenous Components

Proteolytic enzymes hydrolyse the proteins and give rise to free amino-acids. The liberated amino-acids further undergo certain changes as a result of the action of both plant and microbial enzymes. Arginine and serine are deaminated and decarboxylated to acetoin and ornithine.

During ensiling process clostridia brings the major changes in the amino-acids mainly by pathways as given in f., g and h. of Fig. 14.1.

The amount of volatile nitrogen in silage is a reliable indicator of the extent of deamination which is closely related to pH value. The various amines like aminobutyric acid, β alanine, cadaverine, putrescine, histamine, tyramine and tryptamine have all been detected in silage Some of these amines are of considerable importance because of their potential toxicity to the livestock

14.3.4 Pigments

The light brown colour of the silage is because of the action of organic acids on chlorophyll which results in the formation of magnesium-free pigment phaeophytin Carotene is lost considerably under the conditions where heat is produced and the temperature becomes very high. However, in well preserved silages, carotene losses are usually less than 35 per cent which is nutritionally insignificant for dairy animals.

QUESTIONS

1 What is ensiling? Does it increase the nutritive value of forages? Give example
2 Describe the role of microflora in ensiling
3. Explain the biochemical changes which occur in soluble carbohydrates during ensiling
4 Describe the action of protcolytic enzymes on nitrogenous compounds in the ensilled mass.
5. Write in brief about
   (i) Actions of hetero and homo fermentative bacteria.
   (ii) Amines produced
   (iii) Classify the lactic acid producing bacteria in silage.
   (iv) Depigmentation in silage

CHAPTER 15

Hay Making

HAY is the name given to dried forage. This is done mainly to preserve and store the surplus forage. To produce a high quality hay, a good forage must be harvested and dried with a minimum loss of nutrients The primary objective in hay making is to reduce the water content of green plants so that they can safely be stored in mass without undergoing fermentation. This objective must be accomplished in such a manner that the hay is not leached by rain and that the loss of leaves is kept at the minimum.

15.1 Characteristics of Good Quality Hay

1. Good quality hay should be leafy and green in colour since the leaves are richer in carotene, protein, minerals and nutritive value as compared to other parts
2. It should be soft and pliable; and should contain less moisture.
3. It should be free from dust, moulds and other foreign matter.
4. It should have the characteristic smell and aroma of the crop from which it is prepared

15.2 Crops Suitable for Hay Making

The forage crops having soft and thin stems are best suitable for hay making Leguminous crops like green *berseem,* lucerne, cowpea, etc are most suitable crops for hay making. If proper care is taken in curing, shattering of leaves of these legumes is avoided. Among non-legumes green oat is the best crop for hay making. Annual and perennial grasses like *doob* (*Cynodon dactylon*) and anjan (*Cenchrus ciliaris*) can also form good hay. Maize, *jowar, bajra,* teosinte, etc. are more suitable for silage making than for hay making. Early cut graminaceous fodder crops having thin stem are also suitable for making good quality hay

15.3 Stage of Harvesting the Crops for Hay Making

The feeding value of the fodder crops goes down with the advancement in plant growth. At early stage the protein, vitamin and energy contents of the fodder are very high but the dry matter yield of the fodder per unit area is quite low. At the later stages when the crop is in full bloom, the protein value goes down and the digestibility of different nutrients is also reduced drastically, whereas, the production of dry matter is increased. In order to get more nutrients per unit area the fodder crop should be harvested just at pre-flowering stage or at the most when about 10-20 per cent of the crop is in bloom Plenty of sunshine should be available for making of hay from *berseem* and lucerne in the month of February and March

During the kharif season the fodder crops may be cut for hay making during August and September months when the monsoon is on the decline Large quantity of natural grasses is available for hay making in the forest areas of the country The hay prepared from the grasses harvested during later stages of maturity in the month of October November is of inferior quality as the grasses are overripe and have shed the seed.

15.4 Curing of Hay

Drying out begins when the plant is cut The rate of drying depends upon temperature, concentration of dissolved substances, the movement of water and air within the tissues Plants differ in response to drying out. *Berseem* leaves dry more quickly than the thicker stems and thus more rapid drying of leaves contribute to 'shattering' and a loss of the more nutritious leaf tissue. Mechanical rupturing of the cell will increase the drying process The shattering will be reduced by allowing equitable drying of leaves and stems. The sun is an important factor in field drying by providing heat both for rapid fermentation and for more rapid drying and by promoting the destruction of vitamin A and E and formation of vitamin D Depending on the temperature and the technique used losses in feeding value of hay can be reduced.

15.5 Curing Methods

Methods commonly used to make hay from green fodder are field curing and barn drying with either unheated or heated air. Sometimes crushing is done for early drying. A less commonly used procedure involves artificial dehydration at higher temperature for short period of time. The rate at which animals will consume hay dried by the various methods is about the same if the amount of leaf loss and damage due to leaching enzyme and micro-organism action does not differ significantly. The percentages in the harvested DM preserved by the various curing methods are quick drying in an oven 85-90 per cent, barn drying with hot air 85 per cent, barn drying with unheated air 80-85 per cent, field curing without rains 75 per cent and field curing with rain 50-75 per cent. The leafy portion of hays suffers from drying and handling more than stem

A technique for making *berseem* or lucerne hay without loss of leaves has also been developed in the Animal Nutrition Department of Chaudhary Charan Singh Haryana Agricultural University, Hisar which could be adopted This is a simple technique and involves (i) cutting *berseem* or lucerne at the pre-bloom or bud stage, (ii) chopping the wet forage and spreading it in a thin layer (4"-5" thick) on a smooth and clean surface (Fig 15.1), (iii) stirring the drying forage frequently to hasten drying, (iv) gathering of leaves and chopped stem together. Any normal storage structure used for wheat *bhoosa* can be used for this chopped hay.

15.6 Structure Used for Hay Making

The difficulties encountered in hay making and many factors which may increase the losses have led to the use of various appliances and processes designed to control one or the other of the causal factors. The methods adopted consist in their simplest form of using suitable structures on which the hay can be hung so as to allow the rain to run off. The most common method of reducing the losses in hay making is the use of racks, tripod, fence, hurdles, etc. (Fig. 15.2). The tripod which is mostly used consists of three poles hinged at the top and kept apart by three horizontal bars fixed at about a foot or so from the ground. A few set of bars can be fixed at other heights. The hay is heaped round this tripod above the bars and is kept off the ground to allow the circulation of air within the tripod. Hay *Conditioners* as crushers, rollers and crimpers are also used to break the cellular structure of the plants at the time of harvesting. They aid in stoppage of respiration, preventing mould growth, reducing shattering, and reducing the risk of exposure to rain. The dried hay can be baled for easy storage and transportation. However, the feeding value of hay differ with the type of method of curing (Table 15.1).

Fig. 15.1 Curing of Hay by HAU Method

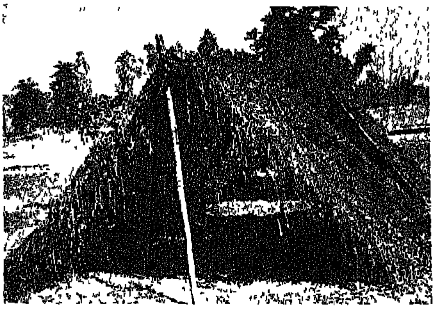


Fig. 15.2 Hurdle Structure of Hay Making

Table 15.1 : Chemical Composition (% dry matter) of Different Types of Hay

Chemical Constituents	*Dried on tripod*	*Dried on wire net*	*Dried on ground floor*	*Chopping and drying (HAU method)*
Dry matter	95.00	93.00	92.00	93.00
Crude protein	18.62	20.37	16.87	23.97
Crude fibre	20.10	23.05	24.45	18.95
Ether extract	3.68	3.08	3.04	4.10
Nitrogen free extract	46.20	39.78	44.79	39.08
Ash	11.40	13.75	10.85	13.90
Calcium	2.55	2.60	3.30	3.10
Phosphorus	0.40	0.40	0.36	0.45
Carotene	4.56	9.40	3.13	12.40

15.7 Chemical Composition of Hay

Hay is more heterogeneous than any agricultural product. Its variable composition remains the major obstacle for reliable evaluation of quality and is a consequence of variety of plant species and growth stages at which the forage is harvested and dried The morphological composition of lucerne hay havested under ideal condition varies from 90 per cent to 35 per cent leaves (highest at immature and lowest at ripe stage) The chemical composition depends on proportion of stem leaf ratio (Fig. 15.3). The second major factor is growth stage as the chemical composition (CP, CF, changes with advancing age (Fig 15 4) and (Fig 15 5) The average chemical composition and nutritive value of some of the hays are given in Table 15 2)

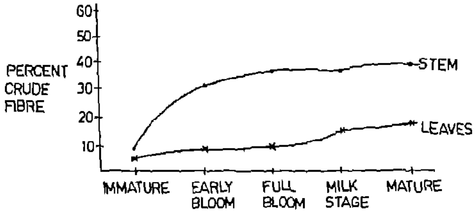


Fig. 15.3 Crude Fibre in Lucerne Harvested at Various Stages of Maturity

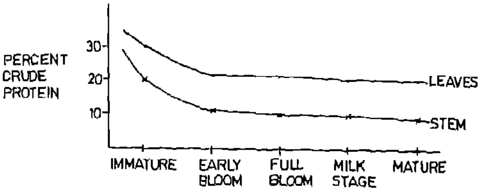


Fig. 15.4 Crude Protein in Lucerne Harvested at Various Stages of Maturity

Table 15.2 : Mean Composition of Hays, as Percentages of the Proximate Constituents and Digestions Coefficients*

	Berseem hay	*Cowpea hay*	*Lucerne hay*	*Oat hay*	*Doob hay*
Dry matter (%)	89 00	89 00	90.00	88.00	87.00
Crude protein (%)	14.70	15.31	21 20	5 26	6 76
Ash %	12 13	13.32	12.74	8 34	12 48
Ether extract %	1 62	1 09	1.41	1 69	0 62
Crude fibre (%)	30.56	34.84	29.41	35.92	24.15
N-Free extract (%)	40 99	35.47	35 18	48 45	55 49
Digestion coefficients					
Crude protein	70	66	77	47	53
Ether extract	29	46	30	74	51
Crude fibre	49	42	51	65	63
N-free extract	77	71	68	64	54
Nutritive value					
TDN %	59	49	51	54	39
DCP %	9 26	6 74	14 73	2 36	3 31

*Data taken from K C Sen and S.N Ray ICAR Bull No. 25.

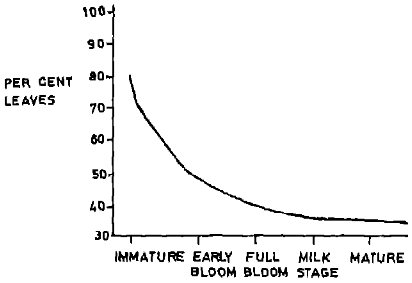


Fig. 15.5 Leafiness of Lucerne at Different Stages of Maturity

15.8 Factors Affecting the Quality of Hay

15.8.1 General Factors

The chemical composition and nutritive value of forage crops depends upon several factors viz. species of the plant, the strain within a species, the type of growth and the response to environmental factors like climate, temperature, weather, humidity, soil and management. It is practically difficult to determine the quantitative effect of each.

15.8.2 Stage of Harvest

Undoubtedly the stage of growth or maturity is a very important factor influencing the chemical composition of forage (Table 15 3). In early stage, the plant has a high proportion of leaves, moisture, protein and mineral content but low fibre and lignin. As the plant growth advances morphological changes take place, leaf growth slows down, stem elongates, floral parts appear and the products of photosynthesis accumulate in seeds. The percentage of crude protein, lipids, soluble carbohydrate and soluble minerals decreases The cell wall becomes relatively more lignified Total dry mater increases but the digestibility of nutrients decreases

15.8.3 Leaf-Stem Ratio

An important factor that determines the quality of hay is the leaf/stem ratio or the proportion of leaves in the crop which varies according to stage of maturity It is observed that when certain legume plants were nearly fully headed, the leaf blades amounted to 38.0 per cent leaf, sheaths 23 per cent, stems 27 0 per cent and heads 12.0 per cent of the dry weight of the entire plant. A month later, when the heads were mature, these percentages were 10.0, 11.0, 39.0 and 40 0 per cent respectively. The chemical composition also changed. Protein content of leaves dropped from 12 0 to 7 per cent and that of stem 5 to 3 per cent. Fibre increased in all parts, slightly in leaves but much higher it the stems. It is, therefore, concluded that any condition that would cause a higher proportion of leaves or delayed development of stems would contribute to higher protein and lower fibre contents of the hay crop

Stems contain about three times as much lignin as the same weight of leaves and stems also contain approximately 70-75 per cent of the cellulose of the plant. The DM digestibility of lucerne stem declined during the maturation period while that of leaves remained the same with little change. The decline in the digestibility of the crop is the result of a reduction in proportion of the more digestible tissues (leaves), a lower concentration of more digestible nutrients and lignification of fibrous constituents

Table 15.3: Average Chemical Composition and Dry Matter Digestibility (DMD) in Per cent of Dry Matter of Different Forage Groups Harvested at Pre-flowering (I), Flowering (II), and Post-flowering (III) Stages

Forage	*Stage*	*DM*	*CP*	*NDF*	*CC*	*ADF*	*HC*	*Lignin*	*Cellulose*	*Silica*	*Ash*	*IVDMD*
Legume Group	I	14 67	23.26	41 07	58 93	34 01	7 06	9 61	23 63	0.77	12 22	73.07
	II	18 23	18 90	48 84	51 16	39 39	9.45	11 15	27 40	1.26	10.71	66.40
	III	28 08	15 68	54 12	45 88	43 17	10 95	12.27	29.28	1 52	9 60	63 58
	Average	20.32	19 28	48 01	51 99	38 90	9 11	11.01	26 77	1.20	10.84	67.68
Non-legume Group	I	15.50	10 49	55.16	44 84	36 10	19 06	5.81	28.36	1 74	10 61	70 10
	II	24 20	7 86	62 45	37 55	40 21	22 24	6 96	30 74	2.29	9 69	63.60
	III	34 37	6.13	69 45	30 55	44 62	24 83	8 01	32 23	2 91	9 48	57 40
	Average	24 69	8 16	62 33	37.67	40 31	22 02	6 93	30.44	2 31	9.72	63 58

DM = Dry Matter, CP = Crude Protein, NDF = Neutral Detergent Fibre, CC = Cell Content, ADF = Acid Detergent Fibre
HC = Hemicellulose, IVDMD = *In Vitro* Dry Matter Digestibility

15.8.4 *Effect of Heat*

Although crushing helps in early elimination of water but a substantial loss of some protein and soluble carbohydrates, carotene and mineral salts occurs. A moderate temperature upto 30-40°C will affect the composition by providing an optimum temperature for enzyme activity and thus hasten the dry matter loss. However, it will also promote more rapid dehydration and stop respiration Because of these opposing effects the loss of nutrients that may occur in any one operation vary and cannot be predicted. Still higher temperature, especially in the presence of oxygen, will cause losses of sugars, amino-acids, carotene and a lowering of nutrient digestibility, vitamin D and E contents. At higher temperature 'non enzymic browning' reaction known as the Maillard reaction occurs This reaction occurs between the carbonyl groups of carbohydrates and the amino groups of amino-acids, peptides and proteins and is accelerated by heat during desiccation This product of reaction is resistant to digestive agents.

Rapid drying in spite of causing some loss in nutritive value, has significant importance over slow drying in certain aspects. Due to rapid inactivation of lipoxidase enzyme and absence of sunlight, the losses of carotene are comparatively lesser. Drying may also destroy the saponines a toxic principle in certain forages.

15.8.5 *Water Content*

The primary objective in hay making is the removal of large quantities of water The water content falls sharply with the stages of maturity. The average water content of forages at the stage when usually cut is made for hay are 60-80 per cent. The leaves contain more water than stem. The time of the day at which the forage crops are cut also affect the moisture content. The percentage of dry matter is highest during the day, from about noon to about two pm (5-10 per cent) and is lowest during night or early morning Harvesting early in the day would, therefore, furnish fodder of higher moisture content but would permit more hours of light for drying during the day.

15.9 Artificial Drying of Forage

Leguminous forages are dehydrated in some of the advanced countries. The forage is first chaffed, and passed through the drier where it is exposed to hot air. Dehydration preserves the nutritive value of the forages better than the field dried hay. However, it is very costly affairs and is not possible to practise it in India on a commercial scale, though on laboratory scale it has been produced. In Tamil Nadu one dehydration plant has been established recently for preparation of leaf meal in the commercial sector

Artificially dried *berseem,* lucerne, etc can be used as protein supplement in the rations of swine and poultry.

15.10 Precautions in Hay Making

1. Forage crops should be cut at the right stage of maturity during sunny days
2. Shattering and loss of leaves be restricted to minimum.
3. There should not be a extraneous material such as weeds, dust, moulds, iron nails in the hay

4 Unnecessary exposure may be avoided to preserve carotene and green colour.

5 Hay should not be stacked while damp.

15.11 Grading of Hay

Feeding value of dry fodder particularly of hay depends upon the quality of product.

Therefore, grades are established to describe the quality of the product. One of these is colour It is generally understood that greenness indicates the feeding value of hay More greenness indicate that the forage was cut early and dried properly. Such hays are palatable, free from dust and moulds and also contain higher amount of carotene. However, the preference of cattle for different types of hay does not seem to be correlated with colour. Although, the preference of cattle for forage is a reasonably good index of its feeding value.

The extent of extraneous material like weeds, straw, etc in the hay is another factor in grading for quality. Leafiness is also an important grading factor in all classes of hays. Leaves contain 2-3 times as much protein as the stem of the same plant. The leaves are also rich in calcium, phosphorus and carotene Leafiness depends on the stage of harvesting of the crop. The more mature the crop, the more easily the fine leaves are lost in handling Legume hays have higher feeding value than non-legume hays. For good hay, the poportion of leaf to the dried weight of the plant, should be at least 35 per cent for *berseem* and 50 per cent for lucerne hay. Poor quality hays are made from miscellaneous grasses and often contaminated with weeds. Some hay crops that have matured sufficiently is also included in this category. Hays containing more proportion of stem is also considered as poor hay

QUESTIONS

1. Mention the crops suitable for hay making along with their stage of harvest.
2. Explain one good method of hay making without substantial loss of nutrients.
3. Enumerate the factors affecting the quality of hay.
4. Describe the characteristics of a good quality hay.
5. Write short note on ,
   (i) Different kinds of hay.
   (ii) Structure for hay making
   (iii) Feeding of hay to dairy animals
   (iv) Precaution during hay making

CHAPTER 16

Nutrient Losses in Hay Making and Storage

SOME of the enzymatic activities continue for some time while the forage is being dried This brings about changes in the chemical composition as a result of which some of the nutrients are reduced in quantity. If the drying is quick, there will be smaller losses as the enzyme activity will cease quickly. During storage also, some of the changes occur in hay These changes in chemical factors associated with drying and storage are explained here

16.1 Nutrients Losses in Drying Hay

The extent of total dry matter losses due to respiration usually ranges from 5 - 15 per cent during field drying depending upon the weather. The total dry matter losses due to leaf shedding are in range of 2 - 10 per cent and 2 - 35 per cent for grass hays and legume hays, respectively. Leaching by water can remove up to 50 per cent of the dry matter, 35 per cent of the phosphorus, 70 per cent of the crude protein and 40 per cent of the nitrogen free extract Field losses of Total Digestible Nutrients (TDN) were 50 per cent if the crop was wet due to rains and still as much as 25 0 per cent, if not rained. Net energy losses are usually less in *bara* than those in the fields.

16.1.1 Carbohydrates

Drying hay at ambient temperature is associated with hydrolytic and respiratory enzymes present in the cell which continue functioning and bring about changes in composition. In harvested forages, carbohydrates are mainly lost by respiration, which is accompanied by loss of dry matter. Soluble carbohydrates are generally lost and since these are highly digestible, the loss in nutritive value is greater than would appear from the loss of dry matter alone. Significant losses in sucrose and fructosan has been observed. This indicates that fructosans are hydrolyzed enzymatically and the released hexoses are then respired. Sometimes increase in sucrose content during wilting is observed. This may be because of its synthesis during drying process. In any case the loss of carbohydrates in one form or another seems to account for most of the dry matter losses during slow drying and wilting

Organic acids are also lost during drying Malic, citric and succinic acids during wilting are decreased. Starch and fructosans are hydrolyzed and the released sugars are then lost by respiration On the other hand, sometime an increase of polysaccharides, presumably by synthesis occurs

16.1.2 Nitrogenous Constituents

Losses of nitrogenous compounds are smaller than carbohydrate losses when the forage is dried at ambient temperature Total soluble nitrogen as opposed to protein nitrogen increases as a result of proteases. There are losses in some of the amino-acids while others are increased There are losses in glycine, serine, threonine, alanine, tyrosine, valine, methionine, leucine and isoleucine while increase in proline, glutamine and asparagine occurs. Total nitrogen is dropped in wilting while free ammonia nitrogen is increased. All forms of nitrogen increase considerably over a period of 24 hrs Since all forms of plant nitrogen are available to ruminants, these inter-conversion do not involve a great loss in the nutritive value

Nitrates are slightly affected by drying but cyanogen glycosides of sorghum, white clover and a few other herbage have been shown to lose their toxicity upon drying This may be due to the denaturation of the enzyme that liberates the cyanide or volatilization of the liberated cyanide of both.

16.1.3 Vitamins

Three vitamins i e A,D and E are affected by drying Carotene, the precursor of vitamin A is unstable in light and air and considerable loss occurs from the action of lipoxidase. Slow drying with an optimum temperature of about 37°C in the sun light may cause over 70-75 per cent destruction of carotene. However, rapid drying quickly inactivates the enzyme and tends to conserve the carotene. Forage is a very poor source of vitamin D However, its prototypes mainly sterols are widely distributed in small quantities. During drying certain sterols on exposure to sunlight develop vitamin D activity. Vitamin E (alpha-tocopherol) is quite high in green leaves particularly during the flowering period. But in matured forages are lower and dried hays are still lower in vitamin E activity The difference may be partly due to the lower leaf-stem ratio of the more mature plants.

16.2 General Effect of Heat

Lignin is apparently increased quantitatively on heating forages A drying temperature above 60°C and especially above 100°C causes an increase in lignin that may be partly or wholly due to the artifact caused by the milliard reaction but may also be caused by condensation of carbohydrates, proteins or lipids with lignin or with one another. Digestibility of protein and sugars also decreases significantly due to drying at higher temperature.

Heat dried forages are, as a general rule, much higher in carotene than those dried in the field or dried slowly under cover. This is mainly due to the rapid inactivation of the lipoxidase enzyme and the absence of sunlight. However, if wilting is prolonged before that drying, a part of the above said advantage could be lost Chlorophyll is also retained during rapid drying in absence of sunlight.

Drying also brings about the denaturation of forage protein and hence bloat is very rare in animals consuming hay Drying may also bring about partial losses in estrogenic activity

16.3 Biochemical Changes during Storage of Hay

Another loss of quality occurs, when hay, after drying is stored Dry matter losses increase with the temperature of storage and with the moisture content of the hay during storage Significant losses of dry matter occur at 35°C and 18-20 per cent moisture i e., as high as 8-10 per cent during storage The losses are chiefly in sugar and other soluble carbohydrates, with some losses of lipids at high humidity, perhaps aided by moulds A variable loss of carotenoids also occurs especially in hays in the presence of air, enzyme activity or micro-organisms. Hay with more than 25 per cent moisture is not safe for storage and might yield a charred product lower in digestibility, particularly of protein Much of the sugar and some protein have been observed to decrease in hay during storage The loss of carotene has been reported to be around 75-80 per cent in about six months. Small increases in fibre and lignin have been reported Spontaneous heating of damp hay leads to the formation of brown and black hays. The composition of brown hay does not differ much from that of poor hay However, if it becomes black on further rising of temperature, severe loss of digestible carbohydrates takes place

16.4 Spontaneous Combustion of Hay

Moist hay produces great heat during storage and in some cases destructive fire results The mechanism of the process is not clear The heat is generated through a process of fermentation, probably enzymatic, in which oxygen is taken from the air and organic matter is transformed into carbondioxide and water From this additional moisture a secondary fermentation due to bacteria takes place. If the hay has external moisture, when first stored, the fermentation is more rapid. The preliminary fermentation raises the temperature to 50°-60°C This temperature causes a second more violent oxidation to take place and the temperature rises to about 80°-100°C At this temperature the hay is charred Ignition will take place in the presence of oxygen If, however, oxygen is excluded ignition will not occur, but the hay will be converted into a mass of charcoal

QUESTIONS

1 Give the losses of nutrients during hay making
2. What are the biochemical changes during storage of hay? Explain them in short
3 Describe the general effect of artificial drying?
4. Describe the spontaneous combustion of hay?

CHAPTER 17

Crop Residues, Agro-Industrial By-Products and Non-Conventional Feeds

THE annual requirement of feeds and fodder in million tonnes are estimated to be concentrate 19.6, dry fodder 347.0 and green fodder 343.6. However, only 11 1 million tonnes of concentrates, 207.0 million tonnes of dry fodder and 227.5 million tonnes of green fodder are available. The gap between the availability and requirement of concentrates and green fooder is very wide, and there is a deficit of 44 per cent for concentrates and 36 per cent for green fodder. In terms of digestible crude protein and total digestible nutrients, the shortfall is 34 per cent and 37 per cent, respectively (Table 17 1).

Table 17.1: Nutrient Requirements for Bovine Population in India (10^6t)

Attribute	*Requirement*	*Availability*	*Deficit*
Energy (TDN)	342	216	37.0
Protein (DCP)	24	16	34 0

Besides grains, three main categories of feeds are . Crop residues, agro-industrial by-products and non-conventional feeds. They are briefly described here.

17.1 Crop Residues

Crop residues (straws and stovers of cereals, pulses and oil seed crops) are mainly fibrous materials and are by-products of crop cultivation due to the intensive cropping and green revolution in India. Crop residues form a high percentage of the total volume of the feeds produced annually Crop residues are deficient in energy, protein, minerals and vitamins which is reflected by the relatively low dry matter and digestibility. The chemical composition and nutritive value of straws and stovers is given in Table 17 2.

17.2 Agro-Industrial By-Products (AIBP)

Agro-industrial by-products refer to the by-products derived in the industry due to processing of the main products They are less fibrous in comparison to crop residues and have a higher nutrient content. Examples of AIBP are molasses, rice bran, oilcakes, *chunies*, wheat bran, coconut cake, apple pemace, pineapple waste, etc The quantities available, nutritive value and toxic factors, if any, present in agro-industrial by-products are given in Table 17 3

Table 17.2 : Nutritive Value of Crop Residues (in per cent)

Residues	*DM*	*Protein*		*TDN*	*Energy (Kcal per kg)*		*Ca*	*P*
		Total	*Digestible*		*Digestible*	*Metabolizable*		
Paddy	91	4.2	1.0	48	2116	1735	0.24	0.09
Wheat	90	3.2	0.4	43	1896	1555	0.15	0.07
Maize	87	5.1	2.2	49	2156	1764	0.29	0.11
Sorghum	91	7.0	3.1	51	2294	1844	0.74	0.28
Bajra	88	2.6	0.9	50	2200	1800	0.30	0.10
Barley	88	3.6	0.6	43	1896	1555	0.30	0.08
Gram	86	3.9	2.4	37	1632	1338	1.40	0.28

17.3 Non-Conventional Feeds

Non-conventional feeds are identified separately, although, they can be components of both crop residues and agro-industrial by-products. The main reason for this is to focus attention on their under-utilization especially in the context of their vast potential in the country.

Non-conventional feeds refers to all those feeds which are not frequently or traditionally used in livestock feeding and/or not normally used in commercially produced rations, and include a variety of feeds originated from different vegetables, crops, trees, animals and industry. The non-conventional feeds could really be more appropriately termed 'new feeds.' Examples of these so-called new feeds are date palm by-products, single cell proteins, feeding materials of animal origin (e.g. poultry excreta, cow dung meal, feather meal, incubator waste, slaughter house waste), poor quality roughages and cellulosic waste from forest and farm residues such as tree leaves, grasses, stubbles, haulms and wines. Some other agro-industrial by-products also exist such as from the processing of sugar, seeds, fruits and vegetables.

The distinction between traditional feeds and non-conventional feeds varies from country to country. In India what may be classfied as non-conventional feeds may in fact be traditional elsewhere. Wider use of non-conventional feeds would designate many of them as traditional feeds in due course of time. The agro-industrial by-products and non-conventional feeds are grouped into following three categories.

(i) Energy rich feeds from root crops, citrus fruits, pineapple, sugar beet, sugarcane, and bananas (e.g. molasses, beet pulp, banana waste, etc.)

(ii) Protein supplements such as oil-seed cakes and meals, by-products from animal and food industries (e.g. feather meal, fish meals and coconut cake).

(iii) By-products from cereal milling (e.g. rice bran, rice polish and wheat bran).

In India, we have been working since 1960's on improving the nutritive value on feed resources and agro-industrial by-products. A number of non-conventional

Table 17.3 : Availability, Chemical Composition and Nutritive Value of Agro-Industrial By-Products as Livestock Feed

Name	*Availability (lakh metric (tonnes)*	*Chemical composition (% DM basis)*							*Nutritive value (% DM basis)*		*Level of feeding*	*Toxic/ incriminating factors*
		CP	*EE*	*CF*	*NFE*	*Ash*	*Ca*	*P*	*DCP*	*TDN*		
1	2	*3*	*4*	*5*	*6*	*7*	*8*	9	*10*	*11*	*12*	*13*
Ambadi-cake (*Hibiscus cannahinus*)	0.30	23.40	6.30	19.70	40.20	10.40	-	-	18.70	63.80	20% level in CM of crossbred calves	Nil
Babul seeds (*Acacia mlotica*)	0.60	17.60	6.00	12.30	59.30	4.40	0.90	0.30	13.80	59.90	30% in CM of crossbred calves	Tannin (5%)
Castor-bean-meal (*Ricinus comunicus*)	0.60	34.80	10.60	33.20	32.20	10.40	-	-	-	-	Detoxifiedmeal at 10% in CM of sheep	Ricin (0.22%)
Cocoa pods (*Theobroma cacao*)	0.30	7.80	2.30	35.10	47.60	7.20	-	-	6.60	63.50	20% in the CM of growing calves	Nil
Coconut pitch (coir waste) (*Cocoa nucifera*)	2.00	1.80	2.90	19.30	70.60	5.40	0.30	0.10	0.00	62.70	25% in CM of crossbred calves	Lignin
Damaged apple waste (*Malus Sylvestris*)	0.20	12.00	2.80	3.50	78.50	3.20	-	-	2.00	70.00	30% in CM of crossbred calves and 12.5% level in broiler mash	Nil
Decaffeinated tea waste (*Camellia assamica*)	0.05	17.90	0.30	12.60	60.00	9.10	5.60	0.80	7.50	58.00	15% in CM of pigs, 10% in broilermash	Tannins
Karanj-cake (*Pongamia glabia*) (Solvent extracted)	1.30	34.10	0.20	4.10	58.20	2.30	-	-	25.50	62.00	15% in CM of crossbred calves and lactating cows	Karanjin and some unidentified factors

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
Kokam-cake (*Garcinia indica*)	0.15	16.60	1.60	4.40	70.00	7.40	-	-	9.30	80.00	50% level in CM of crossbred calves	Nil
Kosum-cake (*Scheichera oleosa*) (Solvent extracted)	0.30	22.11	0.42	7.57	62.10	7.80	0.49	1.09	14.73	79.62	35% in CM of crossbred calves, 17% in broiler mash	HCN (2.4 mg/ 100 g)
Mango seed kernels (*Mangifera indica*)	10.00	8.70	11.00	0.10	75.80	3.60	0.30	0.30	6.10	70.00	10% in CM of milch cattle	Tannins (5-6%)
Mahua seed cake (*Madhuca indica*)	3.00	20.40	2.70	13.30	57.20	6.50	0.40	0.20	9.30	49.80	20% level in the CM of crossbred calves	Mowrin (19%)
Niger-seed cake (*Guizotia abyssinica*)	1.00	34.20	5.70	13.60	37.00	9.50	-	-	32.70	49.40	57% level in CM of crossbred calves	Nil
Panewar seeds (*Casia tora*)	0.30	18.60	7.90	9.90	54.20	9.40	0.90	0.60	15.90	66.00	15% in CM of milch cattle	Crysophanic acid (0.083)
Rice straw (*Oryza Sativa*)	20.00	4.00	1.00	35.40	48.60	11.00	-	-	0.80	41.50	Major roughage	Lignin Oxalate Selenium
Rubber seed cake (*Hevea brasiliensis*)	1.50	35.10	12.50	7.10	34.80	10.50	1.00	0.80	18.60	66.00	25-30% in CM of crossbred calves and milch cattle	HCN (9m/100g)
Sal-seed cake (*Shorea robusta*)	0.70	8.60	2.50	1.30	84.40	3.10	0.20	0.20	0.10	57.80	10% in CM of milch cattle	Tannic acid (8-10%)

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
Spent anatto seed (*Bixa orellana*)	0.30	11.80	4.90	15.80	62.40	5.10	-	-	7.90	67.20	20% in CM of crossbred calves	Tannin (10%)
Spent Brewer's grains	0.50	28.90	5.90	4.20	35.60	25.40	5.70	3.40	-	-	Air-dried material at 50% in CM of buffalo calves and lactating buffalo	
Sugarcane bagasse												
(i) Untreated	200.0	2.90	0.90	41.70	49.60	4.90	-	-	-	-	Low intake	Lignin (8-10%)
(ii) Steam treated	-	3.20	0.90	39.20	52.30	4.40	-	-	-	-	Intake and digestibility improves	Lignin interference decreased
Sunflower straw (*helianthus annuus*)	2.00	2.80	2.00	31.00	52.20	12.00	0.43	0.09	-	-	50% in complete ration for ruminants	Tannin (1.5%)
Sunflower heads (Helianthus annuus)	2.00	7.20	2.90	16.60	62.70	10.60	1.40	0.12	-	-	-do-	-
Tapioca starch waste (*Manihot esculenta*)	0.40	4.90	1.00	19.20	69.30	5.60	-	-	1.80	64.00	25% in CM in crossbred calves	-
Tamarind seed (Decorticated (*Tamarindus indica*)	87.0	19.8	4.7	2.1	70.3	3.1	-	-	11.26	69.92	25% in calf starters	Nil
Tea waste (*Camellia sinensis*)	0.15	28.7	3.6	18.3	43.8	5.6	-	-	9.7	43.3	20% in CM of crossbred calves	Tannins (1.9%)
Vilayati babul pods (*Prosopis Juliflora*)	10.00	12.5	3.6	25.6	53.3	5.1	0.4	0.2	7.0	75.0	20-30% in CM growing calves and milch cattle	Tannins (0.74-1.5%)

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
Warai bron (*Panicum miliaceum*)	0.20	6.2	4.8	18.7	58.2	12.1	-	-	4.5	57.4	30% in CM of growing calves and lactating	Nil
Wheat *bhusa* (*Triticum vulgare*)	1500.0	3.1	1.1	35.7	48.7	11.4	0.26	0.09	0.0	40.1	Major roughage	Lignin (8-11%)
Wheat *bhusa* (*Triticum vulgare*) (Urea treated)	-	6.4	0.9	28.6	52.5	11.6	-	-	4.0	57.0	Improved	Lignin interference decreased
Water hyacinth (Eichhoxina crassipes)	2000.0	19.2	2.2	15.2	47.0	16.4	1.4	0.6	4.2	53.1	Feeding mixed with dry roughage to ruminants	Oxalic acid (2.98%)

CM - Concentrate Mixture, CP - Crude Protein, CF - Crude Fibre, NFE - Nitrogen Free Extract, EE - Ether Extract, DCP - Digestible Crude Protein, TDN - Total Digestible Nutrients, Ca - Calcium, P - Phosphorus

Source Punj, M.L (1988) *AICRP Agril. By-products*, ICAR.

feeds have been identified and are now being utilized in the compound feed industry (Tables 17.4 and 17 5).

17.4 Classification of Livestock Feed Resources

The different feeds available for livestock feeding are broadly classified as under :

(i) Basal Feeds—Cereal grains and their by-products: maize, sorghum, wheat, oat, barley, by-products, such as rice polish, rice bran, wheat bran, etc.

(ii) Vegetable Protein Supplements

(a) Oil-seed cakes, groundnut cake, mustard cake, cotton-seed cake, *til* cake, linseed cake, etc.

(b) Pulses : Gram, *moth, moong, guar, arhar, chunies. gram chuni, arhar chuni, moong, chuni, urd chuni,* etc

(iii) Crop Residues

Paddy straw, wheat straw, *jowar kadvi, bajra kadvi, maize kadvi,* dry and fallen tree leaves, millets straw, pulse straw, straw from oil seed crops, hulls and husks, etc

(iv) Green Forages

(a) Legumes: *berseem,* lucerne, cowpea, *guar,* senji, *metha,* etc.

(b) Non-legumes maize, sorghum,

Table 17.4 : Feed Formulations with Non-Conventional Components

Ingredients	*Non-conventional feature*	*In parts*			
		1	*2*	*3*	*4*
Coconut pith	Yes	5	15	-	15
Straw (ground)	Yes	10	-	5	5
Sugarcane bagasse	Yes	-	-	20	-
Groundnut/cotton seed hulls	Yes	10	10	20	15
Copra cake	Yes	10	-	-	5
Maize cobb, ground	Yes	15	20	-	-
Tapioca waste	Yes	10	5	5	6
Sal seed cake	Yes	6	10	-	15
Rice polish (deoiled)	No	5	16	16	5
Groundnut cake/*til* cake	No	5	10	10	5
Cotton seed cake	No	10	-	10	15
Molasses	No	10	10	10	10
Urea	No	1	1	1	1
Mineral mixture	No	2	2	2	2
Common salt	No	1	1	1	1
		100	100	100	100

Table 17.5 : Compound Feed Formulations with Non-Conventional Components for Cattle

Sl.No.	*Ingredients*	*Non-conventional feature*	*In parts*	
			I	*II*
1.	Tapioca	Yes	10	15
2	Babul seed	Yes	5	10
3	Deoiled mango seed Kernel	Yes	5	5
4.	Sal seed meal	Yes	5	-
5	Sunflower cake	Yes	-	10
6	Niger cake	Yes	10	5
7.	Tobacco seed cake	Yes	10	-
8	Decorticated tamarind waste	Yes	-	10
9	Safflower cake	Yes	5	5
10.	Dried poultry dropping	Yes	-	-
11	Maize/Sorghum	No	10	5
12	Rice bran (deoiled)	No	12	10
13.	Cotton-seed cake	No	15	12
14.	Molasses	No	10	10
15.	Mineral mixture	No	2	2
16.	Salt	No	1	1
			100	100

bajra, hybrid napier, oat, mustard, sudan grass and other grasses.

(v) Fruit and Vegetable Industrial Waste
Rotten and spoiled fruits, apple pomace, empty pods, vegetable leaves, tomato pomace and citrus pulp, peels and seeds, etc.

(vi) Forestry By-products
Sal seed, sal seed meal, neem seed cake, rubber seed cake, fodder tree leaves, babool seed and pods. Tamarind seed, niger seed cake, karânj cake, panewar seed, spent annato seed, mahua cake, etc.

(vii) Sugar Industry By-products
Molasses, bagasse, sugar cane tops and trashes, beet pulps.

(viii) Aquatic Plants and Weeds
Water hyacinth, water spinach, algae, hydrilla, sea weed meal, etc

(ix) Animal By-products and Waste
Frog meal, meat meal, fish meal, blood meal, dried whey, waste milk powder, bone meal, silk worm pupae and larvae, slaughter house waste, etc.

(x) Poultry and Cattle Waste
Egg shells, dead embryo meal, poultry

droppings, poultry litter, poultry dressings, feather meal, cow dung meal, etc.

(xi) Miscellaneous Waste
Used tea leaves, coffee husk, kitchen waste, etc.

17.5 Improvement in Nutritive Value of Crop Residues

Cereal straws and stovers are the major crop residues available for feeding ruminants in India Total annual production of such crop residues in India is estimated to be 410 million tonnes (FAO, 1986). These crop residues, are low in energy, protein, minerals and vitamins. Methods available for their quality improvement are enumerated here

17.5.1 Physical Methods

Grinding and pelleting, soaking and boiling, mixing with green fodders, cooking and steam processing and x-rays treatment, etc.

17.5.2 Chemical Methods

Alkali treatment, ammonia treatment and treatment with oxidizing agents (Chlorine gas, bleaching powder, sodium hypochlorite, mineral acids).

17.5.3 Biological Methods

Addition of enzymes, fungal treatment, etc

17.6 Urea-Ammonia Treatment

Among all the treatments, urea-ammonia treatment of straws and stovers has attracted increasing awareness due to simplicity in use, nitrogen enrichment and improvement in nutritive value.

Urea-ammonia treatment seems to be the economically feasible method in developing countries where straws and stovers are prominent feed stuffs. Four per cent urea treatment with 30 to 40 per cent moisture appears to be feasible for two reasons. First, urea is a heavily subsidised item by the Government of India and second it excludes the use of molasses. being an item not easily available to the farmers. Further, it is a simple process and can easily be processed by farmers. The process has immense application value particularly under draught conditions wherein bagasse as well as other fibrous materials could be utilised for feeding livestock

Urea ammonia treatment of straw also enables animals to consume more It is usually considered that additional consumption is an important factor contributing to the increase in output. Straw and other fibrous materials are normally low in protein. Therefore, the added nitrogen is considered as one of the main advantages of ammonia treatment together with increase in intake and digestibility. It also increases palatability. It has been shown that the nutritive value of treated wheat straw is as good as green sorghum. Ammoniated straw could support a growth rate of 300g/day with small quantity of concentrate and 3-4 litres of milk/day with little green fodder. This results in saving of costlier concentrates.

The improvement in the digestibility of fibrous feeds are due to high rate of microbial digestion, solubilization of hemicellulose and cleavage of linkage between structural components and this leads to easy penetration by the digestive enzymes The ammoniation of straw disrupt the connective tissues of lignified cell wall constituents and also increases the porous areas in the cell wall.

17.6.1 Merits

- Methods for ammoniation are simple and relatively less expensive.
- Ammonia has a preservative effect i.e. high moisture material can be stored.
- Weed seeds are killed by ammonia treatment.
- No extra store for straw is needed.

Increases N content, palatability, digestibility and intake of the straws.

17.6.2 Demerits

Excess ammonia (2/3) is lost into air. Ammonia may cause air pollution.

QUESTIONS

1 Specify the feed and fodder requirement and availability in the country.
2. How can agro-industrial by-products and non-conventional feed resources be utilised in the dairy ration?
3 Enumerate the classification of the entire feed resources in India.
4 What is Urea-Ammonia Treatment? How does it improve the nutritive value of straws? Give its merits and demerits
5 Write short notes on :
   (i) Non-conventional feeds.
   (ii) Crop residues.
   (iii) Basal feeds.
   (iv) Agro-industrial by-products.

CHAPTER 18

Top Feeds

LEAVES of fodder trees are often known as 'Top Feeds.' A large number of trees serve as an important source for feeding livestock. The feeding of tree leaves, tender shoots and thin twigs as fodder for cattle, sheep, goats and camels is an old age practice and still persists in several parts of India particularly in mountainous and sub-mountainous, arid and semi-arid regions. Livestock in South India is dependent to a considerable extent on tree leaves and forest grasses due to the shortage of plain land. Cultivation of fodder crops is practically almost negligible. Fodder trees are grown in these areas to ameliorate the fodder problem to a certain extent.

It is well-known that a number of trees cannot maintain properly adult and growing animals when fed alone. Although they have reasonable high protein content (10-25 per cent), the digestibility of protein is quite low. Tree leaves have been successfully incorporated in the concentrate meals for camels, sheep and goats. The availability of the quantity of dry matter from fodder trees has not been estimated properly. However, about 60 per cent of the total feed available to sheep and goats comes from top feeds. A particular type of tree leaves may not be suitable for all kinds of livestock. Cattle have the least preference for tree leaves, whereas goats have the highest preference to browse on tree leaves, Goats, in general, have performed better than sheep when maintained on top feeds. In poultry rations leaf meals of certain trees are used upto 10 per cent. Attempts have been made to use pods, seeds, seed meal and cake and other by-products available from forest trees as feeds. The trees besides, providing nutritious feed also check soil erosion and build up nitrogen and organic mass in the soil. Trees also provide shade and micro-climate for rural folk and grazing animals.

The dry matter content of most of the tree leaves varies between 20 to 40 per cent. The ether extract is fairly high in the tree leaves but it is not as digestible as in cultivated fodders. The fibre in leaves is highly lignified particularly in the later stages and hence it is poorly digested as compared to the fibre of cultivated fodders The calcium content of tree leaves is two to three times more than that of grasses. However, the phosphorus per cent is quite low which results in widening of calcium to phosphorus ratio in the tree leaves

About 6.4 lakh sq km area excluding tea gardens is under forest cover in India and more than 50 per cent of it is under deciduous forest According to one estimate huge quantity (300-350 million tonnes) of dry matter is available in these forests.

18.1 Fodder Trees

Some of the important fodder trees are described here. The chemical composition and nutritive value of some common fodder tree leaves are given in Table 18.1.

18.1.1 Babul (Acacia nilotica)

Babul grows well in Gujarat, Rajasthan, Punjab, Haryana, Uttar Pradesh, Madhya Pradesh and Maharashtra Three varieties of *Acacia nilotica* are recognized in India The *godi, telia* or *teli* varities have typical spreading and shady crown. It is found extensively in natural forests and is also grown in plantations. Variety *vediana, kaora* or *kauria babul* is smaller in size but has a more spreading crown than the *telia* variety It is found mostly in Deccan and is more xerophytic than the *telia* variety. The third variety *cupressiformis* is characterized by a tall stem and broom like ascending thin branches. It is drought resistant. The leaves of this tree are excellent fodder and are extensively lopped The palatability of the leaves is quite good. Another variety Babul *Acacia arabica* is also quite popular

18.1.2 Khejri (Prosopis cineraria)

Khejri trees are the most predominating desert vegetation that serves as a source of fodder throughout the year It is well adapted to the conditions of arid and semi-arid regions The leaves proliferate during rainy season in June/July It is a moderate size tree and about six to ten metres in height The trees are browsed all the year round but during November/December the leaves along with twigs are lopped and sun dried for storage The leaves are used for stall feeding of camels in particular The lopping of trees is also done in April/May

18.1.3 Pardeshi Khejri (Prosopis juliflora)

Pardesi Khejri grows in all types of dry and arid regions and is as resistant to drought as *khejri* and next in order of dominance. It has bigger thorns, long twigs and is more leafy It is a fast growing tree and the leaves make good green fodder for camel, sheep and goat. The pods are sweet and cater by animals. The dried leaves are stocked and used for stall feeding of camel.

18.1.4 Jhar beri (Zizyphus nummularia)

This is a small thorny bush grown well on sand dunes Its leaves are popularly known as *beri pala* The *beri* is highly drought resistant, almost zerophytic and is seen evergreen for most part of the year During rains, the plant sprouts and the foliage increase in size, remain low but spreads on the ground. The bushes bear red sweet *beri* fruit and is ready for harvesting during early winter The leaves are collected and stored for stall feeding for milk animals as well as camels throughout the year. The dry leaves have a slightly sour taste

18.1.5 Beri (Zizyphus rotundifolia)

Beri is a small thorny tree and along with *Jhar beri* is often found dominating the flora of forests. The leaves are collected and stocked for feeding camel, sheep and goat.

18.1.6 Siris (*Albizia lebbek*)

Albizia lebbek is a deciduous tree having spreading umbrella type crown with dense foilage. It is a tree of tropical and sub-tropical climate where summers are hot and winters are mild. It grows on variety of soils but does well when planted on black soil. The leaf of *Albizia lebbek* is a good fodder. Chemical composition of leaves varies with climate, locality and seasons.

18.1.7 Leucaena leucocephala (Su-babul)

Su-babul is a tree of tropics and subtropics capable of withstanding large variations in rainfall, temperature, wind and drought *Leucaena* can grow on wide range of soils. Good growth is, however, obtained on deep and fertile soils which can supply adequate moisture and nutrients Leaf fodder of *Leucaena* is relished by all types of livestock and as such it is a promising forage crop High mimosine content, however, limits its use as sole feed, and cattle and goat should not be fed solely on *Leucaena*. Defleecing is observed in sheep, if fed on to *leucaena* fodder due to toxic factor 'mimosine' present in it (Fig 18.1)

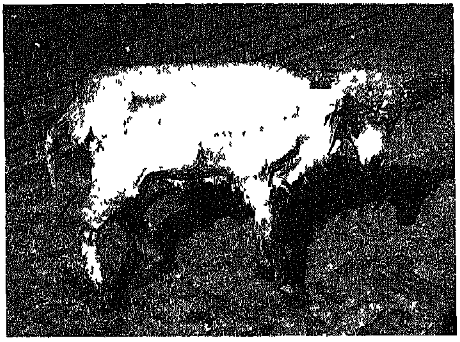


Fig. 18.1 : *Falling of Wool Due to Feeding Leucaena (Mimosine Toxicity).*

18.1.8 Neem (Azadirachta indica)

This tree is found throughout India It is one of the drought resistant trees that grows in all types of soil and climate. The leaves provide fodder for camels as other animal do not relish it much.

18.1.9 Pipal (Ficus religiosa)

Pipal is found in a variety of soils and climates. The leaves are lopped and stocked for feeding to camels and goats.

18.1.10 Bargad (Ficus bengalensis)

Bargad is one of the largest trees, producting plenty of foliage which is eaten by cattle, sheep and goats Small ripe fruits which tall on ground are edible.

18.1.11 Other Fodder Trees

The leaves of Ardu (*Ailanthus excelsa roxes*), Bamboo (*Dendrocalamus strictus*), Mulberry (*Morus indica*), *Pakar* (*Ficus infectoria*), etc are commonly fed to livestock in different parts of the country.

18.2 Methods of Utilization

The leaves of the fodder trees can mainly be utilized as a source of fodder substituted by three methods as given below in their order of preference.

1. Soiling crops.
2. Silage.
3. Leaf meal.

18.2.1 Soiling Crop

This is the best and the most convenient method of feeding the leaves as fodder for sheep and goat. By this method 50 per cent of the tree leaves with their twigs are lopped from the trees and directly fed to sheep and goats with their twigs. But the lopping of the tree and the feeding to animals should be performed on the same day to preserve the nutritive value to its maximum.

18.2.2 Silage Making

The tree leaves along with the soft twigs can be ensiled. By ensiling, the stemy forage crop becomes soft and better utilized by the livestock. The trench silo is the best method of ensiling tree leaves. Addition of 2 per cent of molasses and 1.0 per cent of common salt during ensiling makes the silage highly palatable and nutritious

18.2.3 Leaf Meal

The leaves of the fodder trees can be sun dried or oven dried under controlled conditions and converted into meal. This leaf meal can be fed to animals with or without molasses (at 10 per cent level) and/ or along with concentrate mixture

18.3 Lopping of Fodder Trees

The lopping system of fodder trees should be taken care of as under .

1. Lopping should not be done just before rains.
2. Only two-third lower portion of the tree should be lopped
3. Shoots more than 7-8 cm thick should not be lopped.
4. Lopping should be aimed at new leaves in time. The number of animals should be regulated according to availability of fodder from trees.

18.4 Characteristics of an Ideal Fodder Tree

1. Reasonably fast growing and resistant to drought, frost, diseases and lopping injury.
2. Highly nutritious and palatable with minimum toxic elements.
3. Easy regeneration capacity.
4. Multipurpose tree which may provide wood, pulp, gum, food in addition to fodder
5. Intermediate growth preferably leguminous.

18.5 Limitations and Constraints in Feeding Tree Leaves

Top feeds contain several constraints by way of either deficiency of a particular nutrients or the presence of some toxic ingredients Toxic factors which are most talked about are tannic acid and mimosine

Tannic acid affects the protein metabolism whereas mimosine is uncommon amino-acid present-usually in *Leucaena* species which when ingested in larger quantity does show ill affects like shedding of wool (Fig. 18.1). Some of the minerals such as arsenic, fluorine, molybdenum and selenium are reported to be present at toxic level. However, there are some tree leaves in different states which are deficient in copper, zinc and other minerals. Besides, there are several other toxic principles present in the tree leaves (Table 18.1).

As explained above top feeds are only supplement to other regular feeding material like green fodders, hay, silage and concentrates. Although, tree fodder contains higher amount of crude protein but the digestibility of organic matter is quite low. Hence there is need of supplementation with the other feed stuffs for proper growth and production of livestock.

Table 18.1 : Chemical Composition, Digestion Coefficients and Nutritive Value of Some Common Fodder Tree Leaves

Name of tree	*Average chemical composition DM basis*					*Digestibility coefficients*				*Nutritive value in kg/100 kg dry matter basis*				
												kg/ 100 kg raw material	*MCal/ kg dry matter*	
	CP	*CF*	*NFE*	*EE*	*Ash*	*CP*	*EE*	*CF*	*NFE*	*DCP*	*TDN*	*SE*	*DE*	*ME*
Acacia catechu	13.0	22.6	51.0	4.6	9.7	24	60	31	60	2.9	46.3	33.3	2.0	1.7
Acacia nilotica	11.0	226.7	51.7	3.8	7.1	-	-	-	-	-	-	-	-	-
Albizia lebbek	21.7	31.4	36.1	2.7	9.3	67	9	41	68	11.6	49.3	31.0	2.2	1.8
Azadirachta indica	17.4	17.5	51.3	3.8	10.0	52	58	23	68	8.4	53.3	41.3	2.4	1.9
Banyan (Ficus benghalensis)	9.8	21.9	53.0	2.7	12.5	21	29	26	65	2.0	44.5	29.0	2.0	1.6
Ficus religiosa	9.7	27.0	45.8	2.7	14.9	59	35	22	52	7.0	38.3	27.7	1.7	1.4
Prosopis Spicigera species	15.3	17.5	54.1	3.2	10.0	-	-	-	-	-	-	-	-	-
Ziziphus nummularia	14.5	33.8	46.8	1.6	6.2	47	28	54	69	5.4	51.1	33.0	2.3	1.9
Leucaena leucocephala	16.7	12.6	51.1	7.1	12.5	-	-	-	-	-	-	-	-	-
Bamboo (Dendrocalemus strictus)	14.6	25.6	43.1	1.6	15.2	66	33	58	50	9.3	48.9	32.7	2.2	1.9
Ficus locor (Syn. F infectoria)	11.2	27.7	51.3	2.2	7.7	56	53	62	68	4.0	40.7	24.0	1.8	1.5

CP – Crude Protein, CF – Crude Fibre, NFE – Nitrogen Free Extract, EE – Ether Extract, DCP – Digestible Crude Protein, TDN — Total Digestible Nutrients, DE – Digestible Energy, ME – Metabolizable Energy, SE – Starch Equivalent

There are a large number of top feeds which when fed alone may pose nutritional problems but when fed together with green fodders are valuable source of nutrition for the livestock.

The cost of collection, conservation and transportation of tree leaves from forests and non-availability of proper processing technology are other limiting factors in judicious utilization of top feeds.

QUESTIONS

1 What is a top feed? Explain its importance as fodder for feeding livestock
2 Describe the methods of utilization of tree leaves.
3. What are the various constraints in the utilization of tree leaves as livestock feed?
4 Describe in detail the *Khejri* and *Leucaena* fodder tree.
5 Write briefly about the following :
    (i) Name of five fodder trees with their botanical names.
    (ii) Lopping of fodder trees.
    (iii) Toxic factors in tree leaves.

CHAPTER 19

Improvement and Management of Grasslands and Pastures

THE over exploitation and irrational use of available natural resources due to pressure of human and livestock population has marked the desertification process. Area under wastelands, pastures, fallow lands, etc has decreased whereas livestock population in India has increased considerably About 90 per cent of India's livestock population subsists on natural grasses that are available inside and outside forests. In addition to this, cultivable and uncultivable lands serve as grazing grounds for livestock of the country. Also, the land suitable only for forestry or range management is being brought under the plough. Therefore, grasslands and pastures are very important as feeding grounds for the livestock like, buffaloes, cattle, sheep and goats.

19.1 Definitions

19.1.1 Grassland

Grassland is a natural land surface which is covered mainly by plants of the grass family In proper sense the word 'Grass' includes all plants that are grazed by livestock and hence grassland is used in this broader sense of all plants that are grazed by livestock. Grassland includes both range and pasture.

19.1.2 Range

It is normally considered to be naturally vegetated unfenced land in low rainfall areas grazed by livestock and game animals.

19.1.3 Pasture

Pasture refers normally to the improved and often irrigated fertilized and fenced grazing lands in more favourable precipitation zones which are seeded with domesticated forage plants

19.1.4 Grassland Agriculture

Grassland agriculture is a farming system which includes exclusively the proper use of grass in agriculture and it integrates protection of land from weather As pasture and meadows it provides inexpensive, high quality livestock feed in the form of pastures, hay and silage and in all its forms it is easily cared for and harvested efficiently

19.1.5 Pasturage

Pasturage is synonymous to forage and refers to all vegetation on which grazing animals subsist, such as grasses and grass like plants, shrubs, or weeds, palatable portion of trees and shrubs.

19.1.6 Pasture Management

Pasture management is the science or art of securing maximum sustained use of improved grazing land, forage crops with animal grazing without being detrimental or without any serious damage to the resources or use of the land.

19.2 Advantages of Grazing Lands and Pastures

1 Pasturing of animals is cheaper
2. Cost of production of both livestock and dairy produce and meat, etc. is lowest in case of pasture.
3 There is no expense involved on growing, cutting, transportation or feeding in case of situ grazing.
4 Minimum use of labour

19.3 Indian Grass Cover

For a proper management of any type of grassland, it is necessary to know about the ecology of Indian grasslands The Indian grass cover can be classified into following five groups.

19.3.1 Dichanthium - Cenchrus - Lasiurus Cover

This type of grass cover is found in North West arid and semi-arid regions comprising plains of Punjab, Haryana, Rajasthan, Uttar Pradesh and North Gujarat on soils that are alluvial having sandy loam in texture. The main species found in this region are perennial like *Dichanthium annulatum, Cenchrus ciliaris, C setigerous, Lasiurus sindicus, Eleusine flagellifera, Cynodon dactylon* and *Panicum antidotale.* All of these are valuable forage grasses Legumes found are *Indigofera* and *Crotolaria.*

19.3.2 Sehima-Dichanthium Cover

This cover occurs all over tropical India comprising the Deccan Plateau and extending from South Rajasthan, South Uttar Pradesh, Madhya Pradesh to Bihar and parts of West Bengal This tract has undulating hills with valleys intervening

All types of red and black soils are associated with this cover. Perennial grass species like *Sehima nervosum, Chrysopogon montanus, Themeda triandra, Hetropogon* and *Cympogon Spp , Dichanthium annulatum, Bothriochloa pertusa* and *Cynodon dactylon* are the main grasses in this grassland. The best out of these for forage are *Sehima, Dichanthium* and *Chrysopogon*

19.3.3 Phragmites-Saccharum Cover

This grass cover is found on the eastern humid portions of the lowland plains of Ganga and Brahmaputra rivers basins especially on low lying, ill drained land or in situations in which the water table is high, Main grass species found in this region are *Pharagmists Karka, Saccharum spp. Vetiveria zizanoids* and *Imperate cylindrica*

19.3.4 Themeda-Arundinella Cover

This type of grassland is found in the northern mountains belt, from 450 to 2500 m elevations and includes species such as *Themeda anathera, Arunidinella spp., Chrysopogon spp , Hetropogon controtus* and *Pennisetum orientale.* Legumes are represented by *Desmodium, Crotolaria, Lespedeza* and *Pueraria* Degraded lands contain *Chrysopogon, Bothriochloa, Hetropogon, Eragrostis* and *Themeda anathera*

19.3.5 Temperate and Alpine Cover

This type of cover is found mostly on the hills of Himalayan region in the North and the Nilgiris in the South India It has the characteristics of having species like *Agrostis, Festuca, Poa, Bromus, Holcus, Dactylis* and legumes species like white and red clovers, medics and vetches All these species are typical of grassland cover in temperate lands

19.4 Causes of Low Productivity of Grasslands

Decline in herbage productivity occurs due to variety of causes and these are (i) bad drainage and lack of sufficient plant nutrients in the soil, (ii) putting too many stock into a grassland too early and continued excessive pressure of animal number on the land at the later stages, (iii) the grasslands in India are very poor not only due to grazing but also burning factors that have reduced the grass cover to that condition, (iv) deforestation of grasslands, and (v) poor management of bulk of grazing lands.

19.5 Management and Improvement of Grasslands

The main aim in the management of grasslands is to secure the maximum production for livestock without any deterioration to the soil and production of grasslands. Therefore, it is necessary to ensure that the grassland under consideration is kept at its peak level of productivity as long as possible Protection from grazing is the first treatment required for rejuvenation of grasslands The management and improvement of grazing lands of any region should be done by adopting following techniques.

19.5.1 Control of Weeds and Bushes

Uncared grasslands generally have abundance of shruby and herbaceous weeds which are just not of any use to livestock These weeds compete with the grasses for soil moisture and plant nutrients and in the process adversely affect the grass production. Unwanted thorny bushes/shrubs need to be grubbed out mechanically or manually followed by treatment of stump with weedicide 2, 4, 5 D or Picloram immediately after cutting away above ground plants or bushes. Annual to biennial weeds and bushes can be eradicated by spraying two per cent solution of gramaxone. Even useful fodder bushes viz. *ber* should not be allowed to grow in more than 4 per cent of grazing area to maintain forage production from grassland. Burning to eradicate bushes and weeds should be avoided as far as possible on all grasslands particularly in arid and semi-arid grasslands Eradication of unwanted bushes from the grasslands increases their productivity many times Moreover grass crops conserve the grasslands in many ways e g (i) Prevent soil erosion, (ii) improve soil texture, (iii) increase soil productivity and (iv) increase biological life of soil

19.5.2 Re-Seeding

The quickest and most sure method of improvement in productivity of degraded grasslands is the re-seeding of grasslands with suitable species of grass and legumes

Re-seeding in vulnerable land resource units amenable to wind erosion has to be employed continuously, whereas on level soils with better moisture, this could lead to spectacular recovery of the grasslands in the first year Re-seeding should be well planned and executed carefully. The important steps are selection of site to be seeded, choice of grasses and legumes and their mixture for re-seeding, method of re-seeding, etc In degraded lands devoid of useful fauna and flora of grasses and legumes even partial clearing and strip cropping serves the purpose of introduction of choice species on plain lands *Cenchrus ciliaris, C. setigerus, Chrysopogon fulvus, Dicanthium annulatum* or *Iseilema laxum* are very good species for re-seeding on grasslands of Central India, whereas, *Lasiurus sindicus* and *Cenchrus spp*, are best for arid and semi-arid areas of Northern India For undulating lands *Sehima, Dichanthium* and *Themeda, Arundinella* are good species for re-seeding. The simple mixture of two to three different adapted grasses are generally best which should be mixed with legumes and some soil for re-seeding

19.5.3 Deferred Grazing

It is easy to manage grasslands which are kept for hay making, however, those grasslands subjected to grazing need consideration and care for keeping them in the best conditions. A good grassland has an optimum number of perennial grasses of best species which give new growth with the rains utilizing the food material stored in their root zone. If this new growth is continuously grazed the desirable types will not be able to restore good material and hence adversely affect the growth and production of the next year. If this practice of grazing is continued for a long time, the plants lose vigour and die out resulting into poor productivity from the grassland permanently For good management it is necessary that early grazing should be allowed with intermittent grazing, so that necessary opportunity is given to the grass to recoup its growth interfered by early grazing The deferred grazing is the only option to restore the growth and productivity of grasslands Regarding frequency of cutting, the grasslands should be utilized for cutting at an interval of 30-40 days for better productivity and quality of fodder per unit area and per unit time

19.5.4 Use of Legumes

With the application of fertilizers though the production of grasslands can further be increased at least by about five per cent but the use of fertilizers for improvement of natural grasslands appears to be remote due to their non-availability and higher cost Therefore, the use of legumes in grassland improvement will serve manifold objectives These are not only good substitute of nitrogenous fertilizers, they influence dry matter productivity and its quality from the grasslands Some of the common legumes for grass-legumes mixture are *Stylos, Siratro, Butterfly pea, Lablab bean, Centro, Atylosia* and *Sesbania*

19.5.5 Burning

Burning the grassland is another technique to improve the quality of native pasture. The annual burning in dry cold season promotes growth of spear grass. On the contrary, continuous grazing reduces its frequency and composition Controlled grazing with biennial burning increases the composition of legumes, *Indigofera* and *Atylosia* and improves the productivity of *Sehima nervosum*. Similarly dominance of Buffel grass. Dhaman grass, Blue panic and Sawan grass is found under grazing burning system in desert area.

19.6 Classification of Pastures

Pasture is established on fairly level lands, plains and the inter-dunal areas. Pastures are classified in the following four types·

1. Permanent pastures.
2. Annual or temporary pastures.
3. Short-term or rotation pastures or leys.
4. Supplemental pastures.

19.6.1 Permanent Pastures

These pastures are established through the introduction of perennial grasses or legumes or perennial · grasses + legumes by completely clearing, burning and ploughing the land. Such pastures are grazed year after year and generally have high carrying capacity. Permanent pastures comprise of annual forages which have a high self regeneration capacity of seeds every years. These pastures are found in vast areas in Rajasthan and the major grass species in these pastures are *Lasiurus sindicus, Panicum turgidum* and *Cenchrus spp.* Lucerne can also be used for establishing the permanent and pure legume pasture. Mixture of above perennial grasses and perennial legumes like *Clitoria, Lablab bean,* and *Butterfly pea,* provides a mixed permanent pasture.

19.6.2 Annual Pastures

These include annual cereal or leguminous crops like Gram/*Bajra*/Cowpea/*Guar*/ Dinanath grass with *Stylosanthes humilis* in rotation on cultivated lands with limited rainfall. *Berseem* with oat also provides annual pastures under irrigated conditions. These are grazed in their early stages of growth and in succession to different crops throughout the year

19.6.3 Short-term Pastures or Ley Farming

Short-term Pastures comprise of grasses, legumes and crops grown in rotation. Grasses and legumes are grazed in succession with cultivated and harvested crops for forage or grain crops. This type of pastures for arid regions include *Bajra* for one year, then *Jowar* alone or mixed with *Moth* in between for one year, each followed by perennial grasses with legumes for three years. These are used for hay as well as rotational grazing.

19.6.4 Supplemental Pastures

These are utilized for short period of one to three months in a year in order to ameliorate permanent pastures or range which is the main source of grazing in arid regions of our country. The supplement should be from the temporary or permanent pastures or cover crops sown between crops like maize, turnip, sugar beet or silage crops or fodder trees foliage like *Ziziphus* leaves and *khejri* leaves.

19.7 Establishment of Pasture

The techniques and methods of pasture establishment vary according to soil type and region, means and availability of machinery and materials. The general technology for pasture establishment is given here.

19.7.1 Seedbed Preparation

The field should be firm and free of weeds. Degraded grassland and plain fields should be cultivated with disc plough or a plough followed by packer. The re-seeding after removal of bushes and weeds and full preparation of soil results in good establishment of pasture. Bushes on lands need destruction of aerial growth of bushes before preparation of seedbed Brush movers or brush slashers and heavy disc plough should be utilized for this purpose Herbicides should also be used to destroy the weeds.

19.7.2 Seed Rate, Method and Time of Sowing

These differ according to soils, micro-climate and topography. Generally four to five kg/ha good quality seed in case of *Lasiurus sindicus* and *Cenchrus ciliaris;* five to six kg/ha for *Panicum, stylos, Cenchrus setigerus;* seven to ten kg/ha in *Siratro, Desmenthes* and *Desmodium;* 10-12 kg/ha of Lucerne and 15-16 kg/ha seed for Lablab bean are optimum for good establishment of pastures. Slightly higher seed rates give better pasture establishment

Line sowing at 40-50 cm distance is better in *Cenchrus ciliaris* or *C. setigerus* or mixture of these for better establishment, whereas broadcasting of seed of *Lasiurus sindicus* gives better establishment Re-seeding of large areas of grasslands should be carried out through pre-monsoon broadcasting by labour or by aerial operation. Sowing of seeds by making pellets of 0.5 to 1.0 cm diameter using cowdung, tank silt or sandy loam soil with sufficient quantity of water can also be done. Pellets should be dried properly before sowing.

Shallow sowing of seed and covering with 0 5 to 2 0 cm is necessary for good germination. Sowing of grasses and legumes with pasture land should be done with the onset of monsoon.

19.7.3 Fertilizer Application

Continuous removal of grass-cover results in leaching of soil nutrients which becomes a limiting factor for proper growth of vegetation. Majority of grasses need nitrogenous and phosphatic fertilizers. The sub-soil placement of fertilizer is recommended for desert soils, 40 kg N and 20 kg P_2O_5 per hectare should be applied to obtain higher forage production from grasslands of semi-arid regions with 300 mm rainfall, whereas 20 kg N/ha is sufficient in arid regions grasslands.

19.8 Pasture Improvement

Deterioration of pasture begins when undesirable species replace the valuable forage plants. Improvement of such deteriorated pasture includes protection of land for optimum period to allow establishment of new seedlings, control of animal numbers and relief from over grazing. Desired vegetation can also be restored by seeding degraded pastures with suitable grass and legume species Protection of pasture and controlled grazing alone increases the carrying capacity of pasture almost two to three times. Pasture can be improved by adopting following techniques.

19.8.1 Fencing

For protection against biotic factors, angle iron posts with barbed wire fencing has proved to be most durable and economical in the long run, although the initial cost is high. Fencing is a must before any management programme is launched particularly where pressure from human and animal population is maximum. Fencing of longer area will be cheaper as well as useful for pasture management programme Protection of pasture only for two years increases the forage yield many fold.

19.8.2 Adoption of Soil and Water Conservation Measures

The main objective in the improvement programme is to conserve as much of the rain water as possible on the grasslands, to favour the growth of grasses, as these range land are highly eroded thereby exposing rocky surface, stones and boulders. Contour furrows at a distance of 8-10 metres across the slope have invariably proved to be more effective than any other soil conservation measures Moreover contour furrows are cheapest to maintain in the long run costing Rs 50-200 per hectare and help in increasing the forage production from pastures Harrowing contour furrows or pitting are some of the measures that help in conserving soil moisture.

Water spreading by diverting water from natural water courses to adjoining slopes by putting up small dams to lead the water out in the desired direction also has assumed importance in improving the productivity of grasslands.

19.8.3 Re-Seeding of Pastures

Re-seeding of suitable perennial grasses adopted to the specific agro-climatic conditions is the best resource for increasing the forage as well as animal productivity. However, the topography of the land will be an important factor in undertaking the re-seeding operations on level lands, as the operation is fairly easy and effective Such conditions are generally found in the arid grassland consisting of *Dichanthium-Cenchrus-Lasiurus* type Sufficient information should be gathered about the choice of the species to be sown, the quality of seed, land preparation, moisture conditions and the method of re-seeding in order to make the re-seeding programme successful.

In arid and semi-arid parts of the country with low rainfall (200-250 mm) re-seeding can be done successfully with *Lasiurus sindicus. Cenchrus ciliaris* and *C. setigerus* produce highr forage yield on well drained soil under 300-400 mm and above rainfall zones, and *Dichanthium annulatum* gives higher yield in heavy soil with annual precipitation of 400-500 mm and above *Panicum antidotale* is also useful species for this region. The seed of all these species should be of good quality.

Unwanted bushes like *Mimosa hamata, Balanites roxburghii, S. aegyptica, Gymnosporia montana, Lycium barbatum, Acacia,* and *Sueda fruticosa* should be removed prior to taking up re-seeding programme. One ploughing and disc harrowing is essential for better establishment of perennial grasses. Sowing of grasses in rows 50-75 cm apart with seed rate of 4-5 kg/

ha for *Cenchrus ciliaris* and *C. setigerus*, 5-7 kg/ha for *Lasiurus sindicus*, whereas 2-3 kg/ha for *Dichanthium annulatum* is most appropriate. However, higher seed rate may be needed if grass is sown by broadcasting in dry soil just before the onset of monsoon

19.8.4 Proper Fertilization

Continued removal of the grass cover and consequent leaching may deplete the soil of plant nutrients. This limits the growth of vegetation particularly in arid grasslands which are often subjected to erosion hazards and are highly depleted The productivity of grasslands can be restored and further be increased only by use of fertilizers to supply the deficient nutrients Majority of grasses need nitrogenous and phosphatic fertilizers Fertilizers should be applied based on fertility of pasture land.

Placement of nitrogenous and phosphatic fertilizers 30-50 kg/ha nitrogen + 20-30 kg P_2O_5/ha increases the forage production in the semi-arid regions receiving more than 300 mm rainfall, whereas the response to 20 kg N/ha appears to be favourable in arid regions getting less than 300 mm rainfall. Nitrogen application generally increases the yield as well as protein of the grasses.

19.8.5 Use of Legumes

The role of legumes in grassland improvement is twofold, firstly, they enhance the fertility of soil, and second they provide nutritious forage for livestock. These can be grown in mixture as well as alone. The most suitable legumes for arid and semi-arid range lands are *Dolichos lablab*, *Atylosia*, *Clitoria ternatea*, *Macroptilium atropurpureum* and *Stylosanthes spp*

19.8.6 Weed Control

Both herbaceous and shruby weeds are found to invade deteriorated grasslands although these are not too much problem in arid grasslands However, to eradicate them if any, and to remove their competition for soil moisture and plant nutrients there are various ways such as cutting, digging, burning or the use of chemical weedicides

19.8.7 Timely Harvesting, Fodder Conservation and Preservation

The level of animal productivity from pasture is directly related to its feeding value. Young growth of tropical grasses usually contains sufficient digestible nutrients. Protein content and digestibility decline more rapidly with age in grasses. Therefore, grasses and legumes should be harvested at pre-flower/or flowering stage, when maximum yield and good quality of fodder can be obtained

19.8.8 Stocking Rate for Grazing in Grasslands

Proper stocking rate on the range lands is the first range conservation practice and hence the balance between the number of livestock and productivity of the range need to be maintained keeping in view the growth characteristics of the plants growing in the range lands.

'Excellent', 'Good', 'Fair', 'Poor' and 'Very Poor' conditions range lands having about productivity of 20, 15, 10, 7.5 and 5.0 q/ha, respectively can safely provide year long grazing to 25-30, 20, 17, 13 and

1-6 adult cattle units per 100 hectares blocks, respectively, during normal years. The growth rate of animals is highest when the animals are grazed on the carrying capacity basis (2 4 ha/heifer). By increasing stock rate, the total livestock production is considerably high but the annual grass species are eliminated.

19.8.9 Grazing Principles and Systems

The greatest single factor which causes deterioration of grasslands is over-grazing Hence, a strict control on the number of animals let in for grazing is the first principle of all grazing systems. The number of animals should be fixed on the basis of carrying capacity of the grasslands, which can be defined as the number of animals that can be grazed in a unit area without overgrazing or undergrazing in an average season. In any plan of grazing management the main principles are·

1. To utilize the grass at a time when the growth and reproduction are the least interfered with
2. To utilize the grass when it is most palatable and nutritious
3. To plan grazing based on the carrying capacity of the pasture.
4. To follow better system of grazing.

Utilization of range lands by grazing may be done by one of the following grazing systems

19.8.9 1 Controlled Continuous Grazing

Generally uncontrolled grazing is followed in most parts of the country and it leads to climination of most of desirable species controlled grazing, even if it is continuous can remove this defect to a great extent. The grazing is stopped when a certain minimum number of preferred plants are still left with sufficient seed stock It permits a progressive development of the grassland area.

19.8.9.2 Deferred Grazing

This system consists of delaying grazing in a part of the range land area until after seed-maturity, in order to give a chance for the herbage to make enough growth and accumulate sufficient reserve food material to maintain the vigour of the plants and produce new shoots next year from the seeds that are shed. It is applicable to perennial grasslands. One compartment is completely closed for grazing during the growing season, while the animals are allowed to graze in the other two compartments alternately. It helps in dispersal of seeds, their proper placement on the soil and ultimately good germination next year

19 8.9.3 Rotational Grazing

Rotational Grazing consists of allowing the grazing animals into different sub units of grassland area in rotation at suitable intervals during the grazing seasons, so as to bring about uniform grazing. The quick change over from one compartment to another provides the advantage of giving the animals a nutritive, young herbage and providing a period of rest during growing season The disadvantage is that, it gives no chance for seed formation.

19.8.9.4 Deferred and Rotational Grazing

This system is suitable for grasslands where annual species predominate and when seeding of the perennial species is desired to maintain the density of the grass cover. The grassland is divided into three compartments and grazing is allowed in rotation so that each compartment is grazed for one third of the grazing season and protected afterwards, until the seeds mature By the time, the animals are let into the third compartment the seeds would have matured and got shed and when the animals come back to the first and second compartments the seeds in those would also have ripened and got shed. In the second year, the second compartment is grazed as the first in the rotation. In subsequent years, the same order is followed for each compartment in rotation, so that in three years each compartment would have produced enough seed with the partial protection afforded to the grasses.

19 8.9.5 Zero Grazing of Soilage

This is the practice of cutting the forage by hand or machine and feeding to housed stock. Only high yielding and nutritious fodder crops should be used. In comparison to rotational grazing, the advantage of this system are more efficient fodder use and more uniform intake leading to higher animal production and stocking rate; no need for costly fencing and water supplies, greater tick control and less land requirement.

19.9 Silvipastoral System

Marginal, sub-marginal and other wastelands constitute about 50 per cent of the total area of the country. These lands are found mostly in topical areas. There is always scarcity of good quality forage as pasture grasses are low in protein due to recurring dry season in arid and semi-arid regions. The afforested areas are the valuable source of livestock grazing since time immemorial. The uncultivated and wastelands have good potential for forestry in general and silvipasture system in particular.

19.9.1 Definition of Silvipasture

Silvipasture is the practice of growing forage crops along with forest crops Silvipastoral system is one of the systems of land management in which the interspaces between two rows of trees are utilized for growing nutritious grasses and grass + legume mixture.

19.9.2 Advantages of Silvipasture

Following are the advantages of this system:

1. This system is useful for establishment of vegetation on lands where there is no vegetation or very little vegetation by more useful ones, preferably the dual purpose ones, fuel-cum-forage, timber-cum-fodder species.
2. The fuel-cum-fodder trees and timber-cum-fodder trees build up nitrogen in the soil and serve as shade trees for animals.
3. This system provides nutritionally better quality fodder during lean periods.
4. Fodder trees also improve the micro-climatic conditions and thereby improve conditions for better growth and regeneration of grasses.
5. This system is specially suited to arid conditions

19.9.3 Trees and Grasses for Silvipastoral System

Following are the suitable trees and grasses that could be grown under silvipastoral management.

Trees (Legumes)
Babul (*Acacia arabica* or *Acacia nilotica*)
Kumat (*Acacia senegal*)
Subabul (*Leucaena leucocephala*)
Bilaithi babul (*Prosopis juliflora*)
Khejri (*Propopis cineraria*)
Neem (*Azadirachta indica*)
Siris (*Albizia lebbek*)
Rohida (*Ticomella undulata*)
Dichrostachys cinerarea
Colophospherocum mopane
Hardwickia binata
Grasses
Buffel grass (*Cenchrus ciliaris*)
Dhaman grass (*Cenchrus setigerus*)
Marvel grass (*Dichanthium annulatum*)
Guinea grass (*Panicum maximum*)
Blue panic (*Panicum antidotale*)

A good condition grassland should have 25 to 30 trees per hectare to provide feed, shade and timber to browse during the lean period. By lopping the fodder trees, the green leaf fodder production to the tune of 96 quintals/ha is obtained in case of *Albizia spp. Silvipasture* with trees *Albizia amara, Leucaena leucocephala* and *Dichrostachys cineria* and *grasses, Chrysopogon fulvus* and *Stylos* as pasture components give 6-8 tonnes/ha dry fodder For low rainfall areas *Acacia* and *Prosopis spp.* are the best trees, whereas for medium rainfall *Leucena leucocephale* is the best. All the above grasses are good for silvipasture in limited rainfall areas. Combination of *Subabul* + Buffel grass is good for high green and dry fodder yield under semi-arid conditions

19.10 Fodder Banks

One of the main reasons for poor performance of livestock and dairy industry in our country is due to inadequate and irregular supply of nutritious forage. The situation of fodder demand aggravates more when there is long spell of drought or flooding of cropped areas due to heavy and continuous rains with the result forage crops die and there is no availability of required quantity of fodder irrespective of its quality. To face such adverse situations and to mitigate their effect there is a need to have a buffer stock of dry fodder in our country This can only be done through the establishment of 'Fodder Banks' Fodder Banks are the storehouses or places where huge quantity of dry or conserved fodder is stored as a buffer stock to meet the emergent requirement of fodder for the animals during scarcity periods.

19.10.1 Objectives of Fodder Banks

(i) Preservation storage of surplus fodder to meet the nutritional requirement of livestock during scarcity periods.

(ii) To save livestock from natural disaster.

(iii) To preserve surplus fodder produced during preceding good years

(iv) To stabilize the price of fodder and keep the supply intact in problematic or scarcity areas

19.10.2 Establishment and Management of Fodder Banks

High volume and low value crop residues like wheat *bhusa*, rice straw, *Jowar, Bajra* and Maize stovers and grasses do not permit their immediate and economic transport to distant places where those are needed during natural calamities. Hence, Fodder Banks are being established at the places near to the production area of forage crops preferably adjacent to the forest areas in case of grasses to reduce the cost of transportation, proper storage of the fodder and its timely supply. The Fodder Banks should have two-three sublets depending upon the convenient locations and need of the area for effective supply of fodder. The harvesting and procurement of fodder is done after observing necessary procedure. Government of India, Ministry of Agriculture, Department of Animal Husbandry and Dairying is giving lot of emphasis to establish Fodder Banks and provides required financial assistance for the same. Size of the Fodder Banks depends upon the following factors·

(i) Livestock population.

(ii) Total fodder requirement per annum.

(iii) Frequency of occurrence of droughts/natural disaster in the region/state/area.

(iv) Quantity of anticipated fodder (Targets) to be stored in the Fodder Banks.

(v) Infrastructural facilities and staff available with the organization/state

Fodder Banks should be established and managed by the Animal Husbandry/Forest Department of the States through their supervisory, mechanical and field staff. The supervisory staff should have knowledge about the utility of fodder banks and modalities of fodder distribution from these banks. The volumnious crops residues and grass fodder should be densified with the help of baling machines so as to handle, transport, process and store the fodder in an easy and economical manner. Following points/facilities should be taken into consideration for proper establishment and efficient management of fodder banks.

(i) A.C sheets roofed hay staking yard with platform.

(ii) Electric chaff cutter.

(iii) Chaff-cum-grinder.

(iv) Tractors with trailers

(v) Weighing bridge with shelter.

(vi) Jeep.

(vii) Fire fighting equipment.

(viii) Tubewell with pipelines.

(ix) Molasses store tank

(x) Equipment for urea-molasses blocks.

(xi) Godown for storage of mash ingredients.

(xii) Hydraulic baling machine

(xiii) Trained staff.

(xiv) Area around Fodder Banks should be fenced with barbed wire using iron/stone pillars

QUESTIONS

1. Define grassland agriculture. What are its advantages?
2. What are the different types of grasslands found in India? Write the causes of low productivity of Indian grasslands.
3. What do you mean by grassland? How can the grasslands be managed and improved?
4. Define pasture What are the different types of pastures? Describe them
5. Describe the methods of establishment of pasture.
6. List the techniques of improvement and management of pastures. How are legumes useful in maintaining the productivity of pasture.
7. What are the different systems of grazing? Enumerate the principles of grazing What system of grazing is best for Indian pastures?
8. What do you understand by silvipasture? What are its advantages? List the suitable forage plants for silvipastoral system.
9. Define Fodder Banks and write about their importance in our country.
10. What factors decide the size and efficiency of fodder banks and where should these banks be established and why?
11. Write short notes on.
    (i) Deferred grazing
    (ii) Soilage.
    (iii) Burning of grasslands.
    (iv) Fertilization of grasslands.

CHAPTER 20

Agricultural Meteorology in Relation to Forage Production, Conservation and Animal Behaviour

CROPS require certain optimum levels of various factors of environment like air and soil temperature, solar radiation and humidity of soil and air, etc for their optimum physiological functions. The requirement of these factors not only vary from species to species of crops and animals but the deviation from these result in abnormal growth and performance of plant and animal species. Weather effect can be physical like lodging of crops due to high winds and shedding of grains due to heavy rains, etc Weather factors also influence the incidence of diseases and insect-pests and various cultural operations. In other words, micro and macro-environmental conditions exert a lot of influence on growth of both crops and animals and ultimately their final production. Hence, specific climatic conditions are necessary for optimum growth and performance of plants and animals.

20.1 Definition of Agro-Meteorology

Agro-meteorology is a short form of Agricultural meteorology and is also called as Agro-climatology. It is the study of those aspects of meteorology which have direct relevance to agriculture

Agro-meteorology is a science dealing with meteorological, climatological and hydrological factors having relevance to agriculture and affecting crops and animal performance

When meteorological science is used for the benefit of agriculture, it is called agricultural meteorology. Agrio-climatology is the study of those aspects of climate (micro and macro) which are relevant to the problems of agriculture.

20.2 Importance of Agro-Meteorology

1 Agro-meteorology has direct role in crop production as it concerns to the interaction among various meteorological and hydrological factors and the agriculture
2. It defines the effect of above factors on crops and animals.
3 The knowledge of agro-meteorology is utilized for its practical use and benefits of agriculture and animal production.
4. It helps in the protection and avoidance from adverse climatic factors

5 The incidence of insectpests and diseases of crops and animals is directly related to weather or climatic conditions and hence idea of such association helps in combating the ill-effects of various meteorological factors

6 The climatic factors determine the crops suitable for different regions.

7. Agro-meteorology helps in minimizing agricultural losses through timely weather forecasts and improves the yield and quality of agricultural production

8 Agro-meteorological methods are used in efficient land planning, risk analysis, climatic hazards, production forecasts and adoption of farming method

20.3 Weather and Climate

Weather is the state of these atmosphere in terms of heat, humidity, pressure and wind at a given time i e from few hours to two weeks and place. Thus, heat, humidity, pressure and wind are the basic elements of weather.

Climate is a much broader term than weather and is defined as the collective probable state of atmosphere within a specified interval of time and space at a locality or area

Temperature and precipitation largely determine as to what should be staple crops of a region and the nature of animal industries. Idea of weather pattern of an area helps in interpreting the reason for poor or good crop harvests The weather factors like light, soil moisture, temperature of soil, temperature and humidity of air and other atmospheric conditions are required at optimum level for proper growth and performance of plants and animals

20.4 Climate Relations to Forage Crops

Any given crop has its optimal requirement to the factors of its environment like rainfall, soil moisture supply, mean air temperature, soil warmth and light intensity, etc. The climatic factors regulate and determine the growth and development of crop plants. Each crop has its own set of optimum and tolerable environmental conditions under which it can grow efficiently and perform better This means a crop will not be profitable unless it is grown under climatic conditions which are optimum for its proper growth and better performance Stability of yield over different seasons decides the success of a crop/variety for long standing cultivation. The knowledge about optimum level of climatic requirements for various forage crops is very necessary to manage the higher forage production. The brief account of climatic requirements of some forge crops is given here

20.4.1 Jowar (Sorghum bicolor)

Jowar is a dryland crop grown under erratic rainfall conditions. It is less sensitive to weather changes for longer periods. In India, it is grown for fodder purpose during summer under irrigation and in monsoon season under irrigation as well as rainfed. *Jowar* is a crop of hot, dry and sunny climate. Temperature influences this crop at various stages from germination to maturity. It can be grown successfully in the temperature ranging from 15-40°C, but the optimum is 25-30°C The minimum temperature for germination is 7° to 10°C while optimum is 18-21°C. *Jowar* crop sown in soils with temperature less than 20°C is liable to the attack by seed borne diseases and smothered weeds. Optimum temperature for growth is 27-30°C and temperature above 38°C is harmful

It does fairly well under low moisture conditions. It is best suited to well distributed rainfall ranging from 400 to 700 mm upto flowering. It can tolerate heavy rainfall and water logging for a longer period but its fodder quality and yield is reduced. It can tolerate drought for a longer periods in deep soils because of its deep root system, however, 6-7 inches of stored water is worthwhile for *Jowar* crop. Total water requirement per season is about 58-72 cm in monsoon and summer seasons. High soil moisture or heavy rain at sowing adversely affects germination, crop stand and subsequently its fodder yield.

Jowar gives strong photo-periodic response due to the combined effect of photoperiod and temperature. However, photoperiod is less important for yield Long dark period reduce tillering and hastens flowering, while day temperature is more important for growth and flowering.

20.4.2 Maize (Zea mays)

Maize produces good fodder with mean temperature around 24°C and night temperature above 15°C. Maize cultivation is not possible in areas where mean temperature in summer is below 10°C. The very high temperature also results in less fodder yield. The lower temperature adversely affects the plant and excessive high temperature reduces the growth of the crop at early stages The optimum temperature for growth of maize crop ranges from 9 to 46°C with optimum around 34°C.

Maize, being adapted to humid climate has high moisture requirements. It needs about 750 mm of rainfall for its optimum growth and fodder yield. It requires high moisture in soil for its good germination and plant stand, faster growth and high fodder yield It also requires heavy dose of water before boot stage and its consumptive use of water ranges between 41 and 64 cm.

20.4.3 Bajra (Pennisetum glaucum)

Bajra, a heat tolerant plant, is grown in sub-humid and semi-arid conditions. It needs warm weather, fairly adequate moisture either through rains or irrigation with bright sunshine for its good growth and high fodder yield.

Minimum temperature requirement for germination of *bajra* seeds ranges from 8 to 10°C. The optimum temperature for good growth of this crop is 26 to 29°C, however, it can tolerate temperatures upto to 40°C. *Bajra,* although drought tolerant crop, needs high moisture for higher yield and better quality of fodder. Waterlogging due to heavy rainfall is most damaging for *bajra* crop. Under irrigated or high rainfall (about 850-900 mm) and well-drained areas *bajra* gives high fodder yield.

20.4.4 Oats (Avena sativa)

Oat crop grows well when the climate is cool and humid. Oat prefers cool temperature from germination to flowering otherwise its growth and fodder yield are drastically reduced. Its seeds germinate even at a temperature of 2-3°C but optimum temperature for good germination is around 11°C.

Oat requires minimum 200 mm precipitation for its growth and insufficient moisture during vegetative stage leads to poor fodder yields. Humid and slightly hot climate is best for its good growth.

20.4.5 Cowpea (*Vigna unguiculata*)

Cowpea is a warm weather crop which tolerates heat better than other legume fodder crops High soil moisture and humid air conditions encourage diseases and insect-pests in cowpea. This results in poor quality and less fodder yield. It is highly sensitive to high rainfall and waterlogging. Optimum temperature for faster growth and high fodder yield in cowpea ranges from 20 to 30°C.

20.4.6 Berseem (*Trifolium alexandrinum*)

Berseem, known as Egyptian clover, is a crop of humid and cold climate. It grows well under low temperature provided soil moisture is sufficient When there is severe cold and temperature is below 4°C, the growth of *berseem* becomes slow, whereas under optimum temperature ranging from 15-20°C its growth is very fast and gives frequent cuttings. The growth and fodder yield of *berseem* are reduced when temperature is high, moisture in the field is less and relative humidity is comparatively low. As soon as temperature rises and relative humidity becomes less after mid of April, the *berseem* growth is drastically reduced. This results in flowering and seed formation in the crop Eventually there is no further regeneration and growth in *berseem* crop.

20.4.7 Lucerne (*Medicago sativa L.*)

Lucerne, also known as Alfalfa, is basically a fodder crop of humid temperate climate It requires 8-10°C temperature for germination of its seed. It is tolerant to low (-4°C to -5°C) as well as high temperature (above 35°C). it grows faster under optimum soil moisture and relative humidity with temperature in the range of 10-12°C, and gives frequent cuttings at an interval of 2-25 days and very high yield of fodder.

20.5 Conservation of Fodder in Relation to Climate

Weather factors like temperature, light, humidity and wind have their effect on conservation of various forages. The quality of hay prepared from *berseem*, lucerne and cowpea is better when there is clear sunlight with less humidity in the atmosphere, wind is not blowing and temperature is ranging between 30-40°C The time taken in hay making will be less and there will be minimum losses in the hay under above weather condition. Similarly, both the quality and quantity of silage prepared from various graminaceous forages are much improved provided the weather conditions are favourable for growth of forage crops. The incidence of insect pests and diseases and the moisture content in these crops should be less for good silage preparation The quality of both hay and silage is adversely affected under unfavourable climatic conditions.

20.6 Effects of Climate on Livestock

The climatic factors like temperature, humidity, light intensity, wind storms, rainfall and day length have a direct effect on performance of livestock in terms of drought, milk, meat, wool, haulage, reproduction, growth and development, whereas their indirect effects are through feed consumption. The direct effects of the above factors are more on physiological body functions, infectious and parasitic diseases. However, limited information is available about the role of weather conditions in livestock performance.

20.6.1 Cattle

Cattle are warm-blooded animals. Different breeds of cattle have varying adaptation to different environment. European cattle are more comfortable in the temperature range of -1°C to 15°C, whereas Indian cattle feel better between 10°C and 27°C. Adult animals can tolerate more wide variation in temperature and humidity as compared to newly born animals. For example, 50 kg calf feels comfortable at 15°C, whereas calves weighing 200 kg and 500 kg feel comfortable at 12°C and 10°C temperature respectively, Short horn beef cattle gain more weight at 10°C than 27°C Moderate winds are required for more body weight gain as it improves the feed utilization by the animal.

Temperature ranging from 50 to 75° F is optimum for more milk production with high fat content in cattle irrespective of their body weight. Changes in relative humidity does not have adverse effect on milk yield upto 20°C temperature beyond which high relative humidity amplifies the effect of high temperature towards reduced milk production. Climatic factors influence feed quality, which in turn, influences animal performance. Climatic factors also exert influence on animals through prevalence or control of certain insects and diseases that reduce animal health.

20.6.2 Buffalo

Behaviour of buffaloes is considerably changed by seasonal variation in temperature and humidity The number of docile buffaloes is more in winter than in dry hot and humid weather, while the reverse trend exists with increase in atmospheric temperature These behavioural changes affect milk production adversely in milch buffaloes The number of restless and aggressive buffaloes increases with the insect menance in humid hot seasons. In the hot season/time the river buffaloes prefer to wallow in fresh water, whereas swamp type like to lie in mud holes The body condition of buffaloes is poor in dry season due to non-availability and poor quality of herbage In rainy season the herbage cover on grasslands is good and hence buffaloes graze day and night with intermittent periods of rest followed by wallowing and rumination. Eating rate is indirectly influenced by weather factors through the quality of feeds in stall feeds

20.6.3 Goat and Sheep

These animals are reared in diverse climatic conditions Ideal temperature limits for breeding goat is difficult to set. The environmental requirement of goat and sheep are almost common Sheep can tolerate increased air temperature. Sheep have temperature range of 5 to 15°C for production of meat or wool. Lower temperature increases the fat content in the milk of sheep Body weight gain in sheep increases at temperature around 32°C and relative humidity ranging from 60 to 65 per cent

QUESTIONS

1 Define agro-meteorology What are its advantages in agriculture?
2 Differentiate between weather and climate. What is their relevance to agriculture and fodder conservation?
3 What is the role of climatic factors in the production of cereal fodders?
4. What is the role of climatic factors in the production of legume fodder?
5 How does the climatic factors affect livestock?